SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

ANNUAL CONVENTION NUMBER

Special Features

"Activated Aeration" Process—Chasick

Oxidation of Syndets—Bogan and Sawyer

Cotton Finishing Wastes Reduction—Masselli and Burford

Metal-Finishing Wastes Treatment—Lancy

Algae Control—Fitzgerald and Skoog

Current Research Problems—Heukelekian and Wisely

Twenty-Seventh Annual Meeting—Oct. 11–14, 1954
Netherland Plaza Hotel, Cincinnati, Ohio
(See Page 1182)

SEPTEMBER, 1954—VOL. 26, No. 9

For Effective, Economical Waste and Sewage Treatment, Specify.....

CHICAGO SEWAGE EQUIPMENT

Designed and built especially for sewage and industrial waste treatment, Chicago Sewage Equipment gives you the performance and dependability that only specifically engineered equipment can offer. Years of use in plants all over the country have thoroughly demonstrated the soundness of Chicago operating principles. Constant refinements in design and application by our engineering staff assure you of up-to-date, efficient treatment. There are a few of the reasons why Chicago Sewage Equipment is repeatedly specified by over 95% of active consulting engineers.

VISIT OUR BOOTH at the F. S. I. W. A. Convention, Oct. 11 - 14, 1954. Netherlands Plaza Hotel, Cincinnati, Ohio.

CHICAGO PUMP COMPANY
SEWAGE EQUIPMENT DIVISION

BARMINUTORS
Two New Comminution Developments

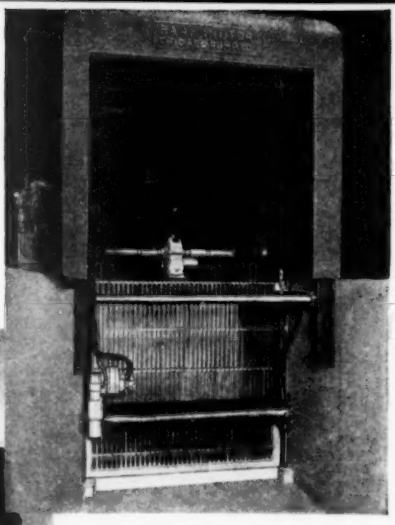
COMMINUTOR
For In-Channel Solids Disposal

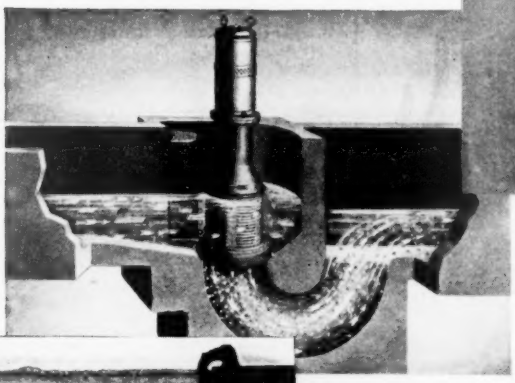
SWING DIFFUSERS
for Continuous, Wide Band Aeration

SCRU-PELLER
Sludge Pumps

FLUSH-KLEEN SEWAGE EJECTORS
They Can't Clog

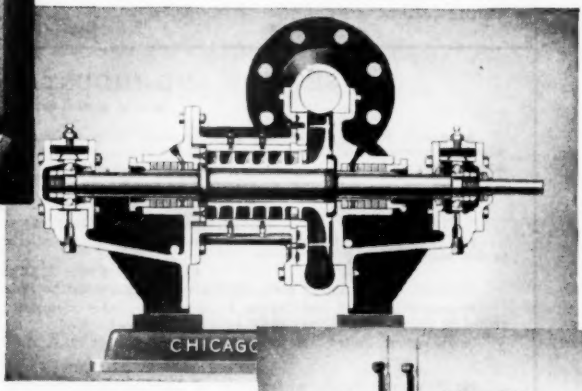
Barminutors cut coarse sewage matter into small, settleable solids without removal from the channel. They bring the advantage of COMMINUTION to sewage treatment plants, pumping stations and out-fall sewers regardless of the shape of the influent channel.



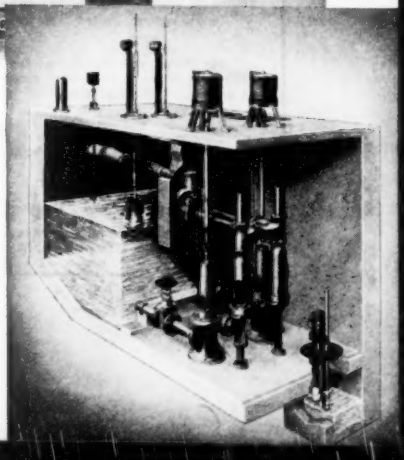


Clean, continuous disposal of coarse sewage — without removal from the channel — is provided by the Comminutor. All coarse material is cut into small, easily settleable solids. 2,500 in service.

Swing Diffusers are the most economical and have the highest aeration capacity of any diffusion system. Simple regulation provides wide flexibility for all kinds of waste and sewage treatment. Individual units easily cleaned without taking tank out of service. 300 installations.



Scru-Pellers chop all coarse and stringy material into small pieces that cannot clog or slow the pump. Simple design assures long life and positive pumping. 8,000 in use.



Flush-Kleen impellers handle only strained sewage. Strainers are backwashed by pump cycle for reliable, clog-proof operation. Over 12,000 in service.

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SEWAGE AND INDUSTRIAL WASTES

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE
Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES
325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES
Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States $1.00 each; Foreign, $1.25 each.

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Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE
Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index.*

Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

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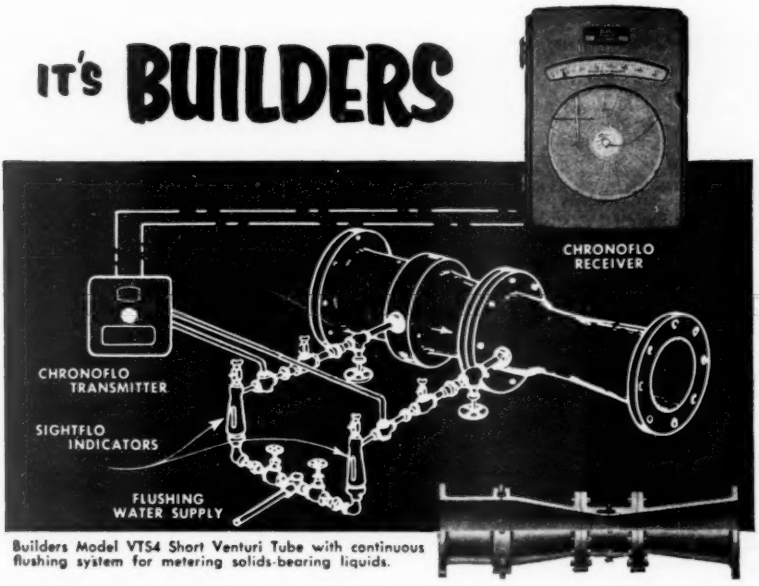

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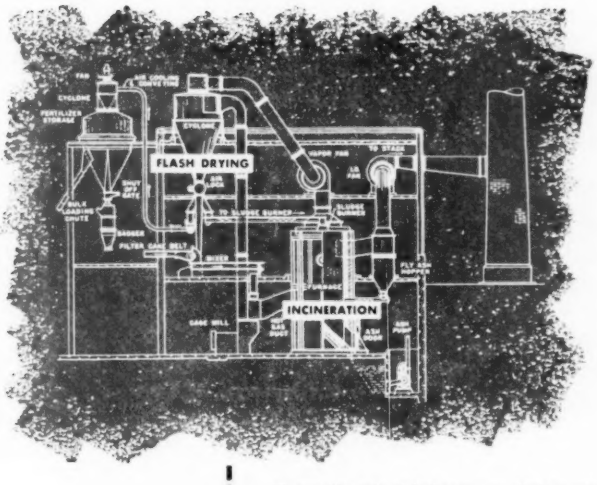

SOME FACTS ABOUT THE HEAT DISPOSAL of SEWAGE SLUDGE

Even though dried sewage sludge can often be sold at from $5.00 to $20.00 a ton — remember that is not *always* the case.

If sewage is contaminated — with grease, fibre, etc., for example — you may find the *only* thing to do is to incinerate the sludge. On the other hand, even though the sludge may not have the highest chemical analysis for fertilizer — it still can be marketed as a soil conditioner — thereby eliminating the ash disposal problem.

The C-E Raymond System of Flash Drying and Incineration is the most popular . . . most versatile on the market today. That's why you will find a C-E Raymond System to provide one or all of the following processes . . . controllably, accurately, economically:

1. **Flash Dry sludge.**
2. **Flash Dry and Deodorize.**
3. **Flash Dry and Incinerate.**
4. **Flash Dry, Incinerate and Deodorize.**
5. **Incinerate only.**
6. **Incinerate and Deodorize.**
7. **Flash Dry and Deodorize in conjunction with refuse and garbage incineration — plus incineration of sludge if desired.**

C-E Raymond Systems now in service or on order serve an equivalent population of more than 17,000,000 people — in communities ranging from 6,000 to 3,600,000 in population . . . in every section of the country, and even overseas.

Whatever your requirements — there is a C-E Raymond System that will satisfy them precisely. Let one of our engineers show you or your consultants how this leading system of sludge disposal will work for you.

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ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

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Association	*Place*	*Time*
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Andrew Jackson Hotel, Nashville, Tenn.	Sept. 20–22, 1954
North Dakota Water and Sewage Works Conf.	Hotel Dakota, Grand Forks, N. D.	Sept. 22–24, 1954
Georgia Water and Sewage Assn.	Georgia Institute of Technology, Atlanta, Ga.	Sept. 22–24, 1954
Missouri Water and Sewage Conf.	Hotel Governor Jefferson City, Mo.	Sept. 26–28, 1954
South Dakota Water and Sewage Works Conf.	Lawler Hotel Mitchell, So. Dak.	Sept. 28–30, 1954

TWENTY-SEVENTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
Ohio Sewage and Industrial Wastes Treatment Conference
Netherland Plaza Hotel, Cincinnati, Ohio
October 11–14, 1954

Pacific Northwest Sewage and Industrial Wastes Assn.	Hotel Eugene Eugene, Oregon	Oct. 21–23, 1954
Canadian Institute on Sewage and Sanitation	Windsor Hotel Montreal, P. Q. Can.	Oct. 25–27, 1954
New England Sewage and Industrial Wastes Assn.	Hotel Stratfield, Bridgeport, Conn.	Oct. 28, 1954
Rocky Mountain Sewage Works Assn.	Broadmoor Hotel, Colorado Springs, Colo.	Nov. 8–10, 1954
Florida Sewage and Industrial Wastes Assn.	Sorrento Hotel, St. Petersburg, Fla.	Nov. 8–10, 1954
North Carolina Sewage and Industrial Wastes Assn.	George Vanderbilt Hotel, Asheville, N. C.	Nov. 8–10, 1954
West Virginia Sewage and Industrial Wastes Assn.	Hotel Prichard, Huntington, West Va.	Nov. 9–10, 1954
Nebraska Sewage and Industrial Wastes Assn.	Keystone Hotel, McCook, Nebraska	Nov. 11–12, 1954
Oklahoma Water, Sewage and Industrial Wastes Conf.	Student Union Bldg., Stillwater, Okla.	Nov. 15–20, 1954
New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza, New York, N. Y.	Jan. 20–21, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955

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PUMPS—PNEUMATIC EJECTORS

SEWAGE TREATMENT EQUIPMENT

Yeomans Brothers Company manufactures a complete line of equipment for both primary and secondary sewage treatment. Only Yeomans gives "one responsibility" service for the manufacture of equipment for both trickling filter and activated sludge treatment systems.

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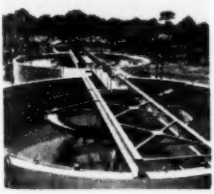

Spiraflo Clarifiers. Highest B.O.D. and suspended solids reductions at lowest cost. Unbiased tests by sanitary authorities show removals of more than 70 percent suspended solids and 45 percent B.O.D. in primary Spiraflo Clarifiers.

"Streamline" Sludge Collectors. Drag line type. Available with surface skimming and sludge collection for primary tanks and with sludge collection alone for secondary tanks.

Center Drive Clarifier. Conventional type in two sizes for small tanks up to 50 ft. diameter and larger tanks over 50 ft. diameter with or without surface skimming.

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There is a Yeomans design of proved superiority for every biological filtering plant requirement.

"Aero-Filter". A high capacity biological trickling filter utilizing the Halvorson-Smith process. Recirculation for dilution purposes is NOT required. Single-stage operation produces raw sewage B.O.D. reductions of 85 percent and greater; two-stage operation gives results comparable to activated sludge treatment at lower cost with raw sewage reductions from 90 to 94 percent.

Standard Rate Distributors— Distribute evenly across entire filter bed; non-clogging flat spray nozzle produces a fine well aerated spray which carries down large quantities of oxygen. Yeomans "Leveler" permits correction of several degrees without dismantling.

"Water-Wheel" Distributor—Simple and positive in operation at all flows and even at lowest rates. Rotating distributor arm secures even distribution.

"Package" Sewage Treatment Plants—Complete low-cost installations for small communities, outlying housing developments and individual industrial plants. Utilizes the Spiragester, a Yeomans design which performs the functions of both primary clarification and digestion and meets the needs of primary treatment in a single structure.

For individual bulletins and detailed information call your local Yeomans Representative listed in the Yellow Pages of your telephone book under "Pumps," or write direct

ACTIVATED SLUDGE SYSTEMS

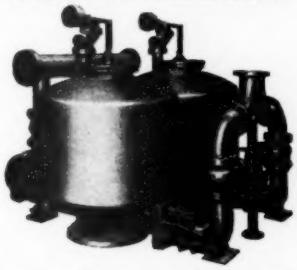
Hi-Cone Mechanical Aerator produces an ideal balance of intense surface aeration and rapid circulation to support high concentration of rich activated sludge and secure intense biological oxidation of the sewage. Hi-Cone will treat at least 50 percent more sewage than old type cones in the same size aeration tank with no increase in power consumption, secures better B.O.D. reduction than diffused air plants in the same aeration period, gives circulation three times greater; tank contents completely circulated approximately every five minutes.

Sludge Digester Mechanisms for use with circular fixed cover sludge digestion tanks. Provide complete facilities for scum breaking, sludge concentration and collection of digester gas. Two types for large and small installations.

Non-Clog CENTRIFUGAL Sewage Pumps

Yeomans builds non-clog pumps of both horizontal and vertical types for every need. Capacities of 50 to 24,000 g.p.m. operating against heads of 10 ft. to 130 ft. and higher.

PNEUMATIC SEWAGE EJECTORS



Recommended for handling sewage flows where gallonages are limited but solids are not.

SHONE® Pneumatic Ejector

The simplicity of design and the positive, completely mechanical operation have enabled the SHONE to give almost unbelievable records of service. It cannot clog; it has ample excess capacity; there is no septic action, no odor, no gas. It operates with compressed air, gases or steam; there is nothing to get out of order and it requires a minimum of attention.

Expelsor Sewage Ejector, a simple device which fills all pumping needs in smaller waste removal systems.

Packex Pneumatic Sewage Ejector, a factory-assembled unit ready for inlet and discharge connections.

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There's no customer

Ewing Galloway

This is Detroit—the Automotive Capital of the World.

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Old print showing Detroit about a century ago, from the Canadian side of the river.

MODERNIZED **cast iron**

like an old customer!

DETROIT installed cast iron water mains 116 years ago... and installs them today!

One hundred years ago, Detroit was a city of 40,000. Today it is the Automotive Capital of the World. Today's two million population (estimated) requires over three thousand miles of mains of which 97% are cast iron. Several of these mains are still functioning after a century and more of service. Customers served have increased from 5300 a century ago to nearly 400,000 (city only).

One of several cast iron water distribution mains still functioning in Detroit after a century and more of service.

When you have customers with an unbroken record of buying your product for over a century, you naturally prize them. They're scarce in any long-established business or industry. The cast iron pressure pipe industry is proud to have 60 such customers—utilities that have been buying cast iron pipe for water or gas mains for 100 years or more.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher, and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

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accurate measurement and control

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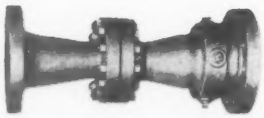

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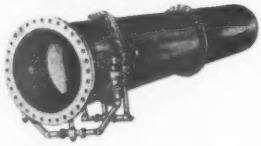
For accurate measurement of hot or cold water, gases, sewage, sludge or trade wastes under wide ranges of pressures. Flanged, bell, or spigot ends in any size or design . . . cast-iron, cast steel or steel plate, bronze, or combinations.

ELLIPTICAL VENTURI TUBES



WRITE FOR BROCHURE

Developed specifically for accurate measurement of low velocity sewage, sludge or heavily laden trade wastes—flowing under low pressure conditions. Flat top prevents air binding! Flat invert is self-scouring!

PARABOLIC FLUMES

WRITE FOR BULLETIN 800

Specially designed to measure sewage, sludge, and trade wastes under low heads or open flow. Can be used for indicating, or with meter to record and totalize. Simple to install. Full 20 to 1 flow range. Flanged, bell or spigot inlet in 6" to 36" standard pipe sizes.

PITOT EQUIPMENT

WRITE FOR BULLETIN 1300

Leaks and line breaks are quickly located with Simplex pitot rods, manometers and recorders. Light-weight, compact design makes them truly portable. Invaluable for overall survey of your distribution system's efficiency.

FILTER GAUGES

WRITE FOR BULLETIN 1000

Indicate and/or record essential data on rate of flow, loss of head, sand expansion, water level, etc. Attractive units with easy to read dials. Floor stand mounting—or Operating Tables for convenient centralized control.

CONTROLLED CLOSING VALVE

WRITE FOR BROCHURE

Prevents surge and water hammer damage when filling larger size pipe lines. Controls speed of line closure, vents air and, if necessary, discharges water to prevent damage. Admits air to protect against pipe collapse from line breaks.

SIMPLEX VALVE & METER COMPANY

SIMPLEX FLOW METERS

TYPE MO METERS

Most accurate inferential type instrument for water, sewage, sludge, industrial liquors. Indicates, records, totalizes. Measures within ±2% over ranges up to 20 to 1. Easy-to-read, evenly-spaced rectangular chart. Wall, floor stand, or panel mountings.

WRITE FOR BULLETIN 500

REMOTE TRANSMISSION

PNEUMATIC — New Simplex Laminair® is fast and accurate. Permits centralizing instruments in main control panel away from primary devices.

ELECTRIC — New Simplex Orthoflow® transmits data over in-plant circuits and leased telephone channels. Accuracy within ±2% for ranges up to 20 to 1.

WRITE FOR BROCHURE

TYPE H METERS

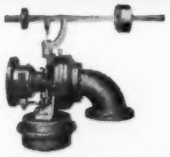
Mercury-float type indicating, recording and totalizing unit. Gives ±2% accuracy at any point for flow ranges up to 13 to 1. Evenly spaced scales make accurate readings easy. Wall, panel, or floor stand mounting.

WRITE FOR BULLETIN 401

FLOW RATE CONTROLLERS

SLUDGE CONTROLLERS—Accurately control flow of sewage, sludge, trade wastes. Most accurate primary device, a Simplex Venturi Tube, has a special throat section of flexible rubber—measures as it controls! Motor-driven clamp adjusts throat . . . keeps flow at control point. Viscous flows contact no moving parts.

WRITE FOR BROCHURE



TYPE S FLOW CONTROLLERS

Keep flow constant despite changes in head of filter effluent or wash water. Control within ±3% over 5 to 1 range. Exclusive balanced guillotine valves quickly respond to slightest change. Standard sizes from 3" to 24".

WRITE FOR CATALOG 004

SIMPLEX AIR RELEASE & INLET VALVES

AIR RELEASE VALVES

Vent air accumulations to eliminate binding at high points, increase pumping efficiency. Simple, rugged 1" and 2" sizes for up to 250 psi. Special valves available for up to 800 psi.

WRITE FOR BULLETIN 1200

AIR INLET VALVES

Prevent collapse of thin-walled pipes from sudden pressure drops in gravity lines. Simple, reliable float control quickly admits air to break vacuum. Available in 4" to 10" sizes.

WRITE FOR BULLETIN 1202

COMBINATION INLET-RELEASE VALVE

One compact unit with a 2" connection does work of two separate valves! High discharge and inlet capacities. Invaluable for venting large quantities of air when filling systems.

WRITE FOR BULLETIN 1203

RELATED SIMPLEX® EQUIPMENT

- FLOW REGULATORS
- LARGE DIAL GAUGES
- INSERT-TYPE VENTURI TUBES
- SPECIAL VALVES
- TAILOR-MADE MEASUREMENT & CONTROL EQUIPMENT

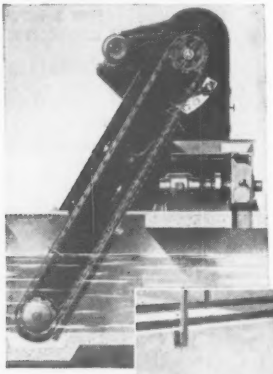
SIMPLEX VALVE & METER COMPANY

we treat them all like

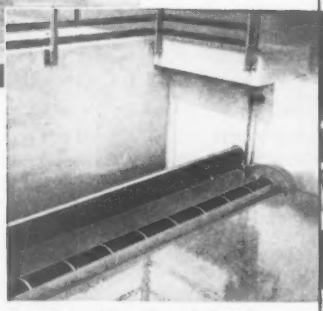
finger prints!

Just as no two sets of finger prints are ever alike, so, too, are all sewage and waste treatment problems *different.* Velocities, head loss, capacities, site conditions, tank or chamber hydraulic conditions, and many other factors vary from plant to plant. That is why we at Chain Belt have no standard answer to a treatment problem. We study each application carefully, and from our broad background of experience recommend the type and size of equipment you need for most efficient, economical results. From the broad range of Chain Belt Sewage and Waste Treatment Equipment, we select the exact units that can be best adapted to your particular conditions.

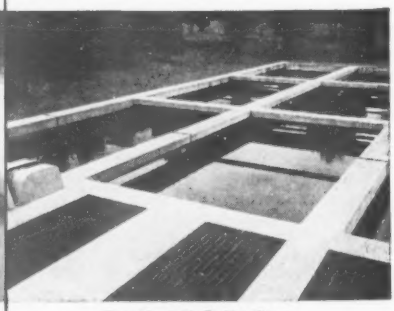
So, don't just specify equipment. Ask your nearest Rex Sanitation Engineer to work with you to assure the results you want, or write direct to Chain Belt Company, 4606 W. Greenfield Avenue, Milwaukee 1, Wisconsin.



Rex Mechanically Cleaned Bar Screens and Triturators



Rex Reto-Skim Revolving Pipe Skimmers

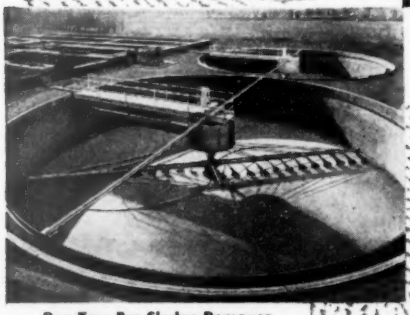


Rex Verti-Flo® Clarifiers

CHAIN BELT COMPANY

Rex Grit Collectors

Rex Conveyor Sludge Collectors



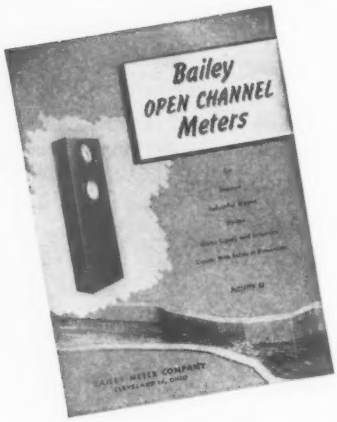
Rex Tow-Bro Sludge Remover

district sales offices in all principal cities . . .

For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

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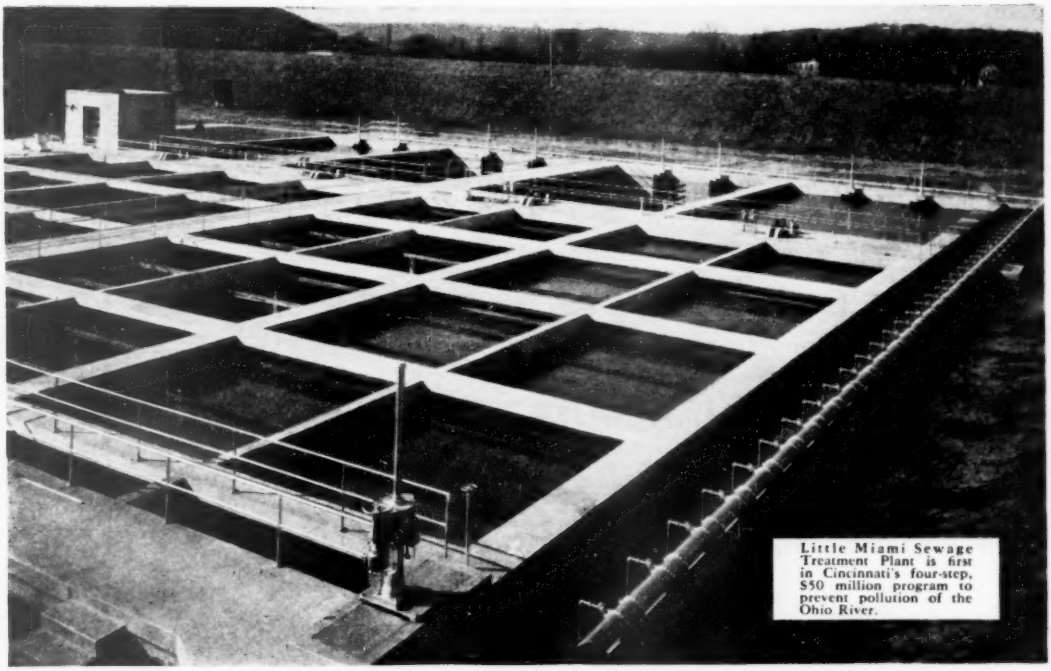
METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

VISIT OUR BOOTHS 55-56 — SEWAGE WORKS AND INDUSTRIAL WASTES CONVENTION — CINCINNATI, OHIO — OCTOBER 11-14



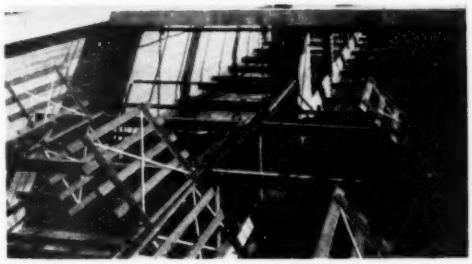
Little Miami Sewage Treatment Plant is first in Cincinnati's four-step, $50 million program to prevent pollution of the Ohio River.

It's LINK-BELT collectors and mixers at Cincinnati's new sewage treatment plant

BECAUSE the 900-mile Ohio River is the water supply as well as waste outlet for many communities in the eight states bordering it, Cincinnati's sewage disposal problems had to be resolved with consideration for downstream cities. Havens and Emerson, Cleveland consulting engineers, chose Link-Belt mixing-settling equipment.

The outcome: a treatment system designed for almost complete removal of settleable solids . . . 45 per cent removal of total suspended solids, estimated at 250 parts per million . . . 65 per cent B.O.D. reduction of raw sewage with 270 parts per million. While present flow is 18 mgd, actual capacity is 29 mgd, expected to be reached about 1980.

In both breadth of equipment line and depth of experience, Link-Belt is well qualified to handle your sewage treatment requirements—be they large or small. Our sanitary engineers will be glad to work with your engineers, chemists and consultants to provide the finest in modern water, sewage or industrial liquids treatment.



Link-Belt Straightline mixers and collectors in flocculation compartment (foreground) combine to provide maximum solids removal in shortest time. Link-Belt 30 and 48-in. belt conveyors are also used in processing sludge.

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 13.640

IMCO TWO PIECE SEWAGE FILTER TILE

Engineer's preference due to—

MAXIMUM AERATION

MAXIMUM STRENGTH

MAXIMUM CHANNEL DISCHARGE

GUARANTEED CLEAN CHANNELS
with clam shell loading of stone from the beginning of stone placement

❖

Write for Catalogs or advice on your problems

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INDUSTRIAL MATERIALS COMPANY
"IMCO"

Somerset Street & Trenton Avenue
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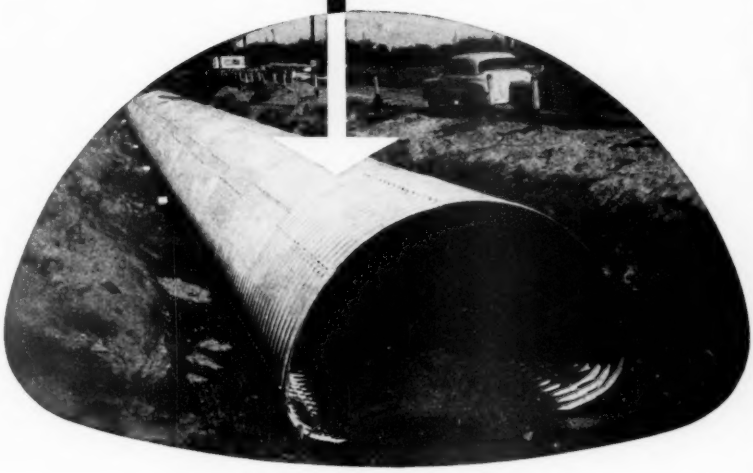
THIS SHAPE solved city's sewer problem



The problem was to enclose an open storm sewer, yet retain adequate waterway under limited headroom. A single round pipe of the right capacity would not fit the headroom, and a multiple installation of smaller pipe would add to the expense.

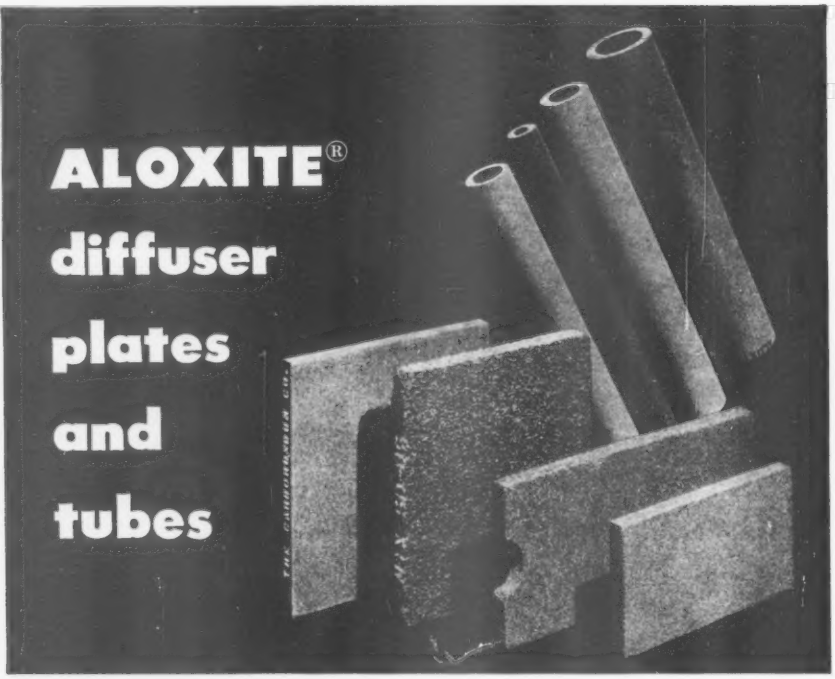
The solution was Armco Pipe-Arch, a single structure that met both the water capacity and headroom requirements.

There's a type and size of Armco Corrugated Metal Structure for almost every municipal sewer need. Standard Corrugated Pipe and Pipe-Arch meet normal service conditions. Where severe corrosion is a factor, you can specify Armco ASBESTOS-BONDED. It withstands acidic as well as alkaline wastes. Armco PAVED-INVERT will guard against erosive flow.

For larger sewers there is Armco MULTI-PLATE Pipe or Pipe-Arch. Write for complete data.
Armco Drainage & Metal Products, Inc.,
1984 Curtis Street, Middletown, Ohio.
Subsidiary of Armco Steel Corporation.

Armco Sewer Structures

ARMCO



made from the only TIME-TESTED MATERIAL

When considering air diffusers, these facts are worth keeping in mind: Of the many aeration methods and materials tried since the discovery of the activated sludge process (in 1915), *only one* has stood the test of time. Only porous ceramic diffusers have been used with continued success. And more installations have been made with ALOXITE aluminum oxide diffusers than all makes combined. Hundreds are still operating — many after over 20 years' service.

The inherent advantages of ALOXITE diffusers are: (1) A highly uniform grain structure. This assures uniform, small-bubble diffusion, and, consequently, optimum absorption. (2) A smooth, low-resistance surface. The glass-like ceramic bond that coats each grain minimizes pressure loss or clogging. (3) Permanent resistance to corrosion. (4) Adaptability to practically all cleaning methods. (5) Great strength and ruggedness.

ALOXITE diffusers are available in plate or tube form, and in a full variety of grades. This permits maximum flexibility of design. It also lets you select the exact grade for optimum diffusion, (consistent with air supply quality, pressure loss characteristics, and overall life). This is particularly important since the introduction of the oxygen absorption test.

Write for free 56-page booklet.

CARBORUNDUM

Registered Trade Mark

Dept. N-94, Refractories Div. **The Carborundum Co., Perth Amboy, N. J.**

WATCH YOUR WASTE LINE

THE **Sediflotor**
Trade-Mark
CLARIFIER

will help you REDUCE
your WASTE instead
of your PROFIT

Learn how the "SEDIFLOTOR" Clarifier can help you streamline your waste water handling . . . with IMPORTANT SAVINGS to you. This coupon can bring details . . . quickly.

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Plants in Chicago and Joliet, Illinois
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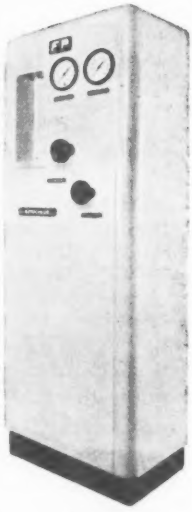
how much does it cost to run the old model?

Even if you bought new today one of the old model chlorinators, you can actually scrap it right now and save money!

How can such a thing be?

In hundreds of installations using **F & P** Chlorinators it has been proven conclusively that costs of operation and servicing are so much lower than old style chlorinators that it actually *costs money* right from the first day of operation to have an old style chlorinator.

Fischer & Porter designed this new chlorinator right from the floor up. New materials are used throughout to make it impervious to corrosion. Encased in a fibre-glass cabinet, the new **F & P** Chlorinator handles chlorine —in fully enclosed, tightly sealed, corrosion resistant pipes and components. It is the best, safest, most efficient, easiest operating chlorinator ever devised.



Right from the purchase price you save money on an **F & P** Chlorinator And you save money every day thereafter, because you have less maintenance cost, less chance of breakdown with sky-high service charges, no need for multiple reserve units or scores of spare parts, no wasted chlorine gas lost through water seals.

As a top municipal official, as an ethical consultant, as a practical operating man—you must admit if all these things we say are true, you can't afford to ignore this new chlorinator.

It won't cost you a single penny to *get the facts* about the F & P Chlorinator. It will obligate you in no way. Why not write today?

complete process instrumentation

FISCHER & PORTER CO.

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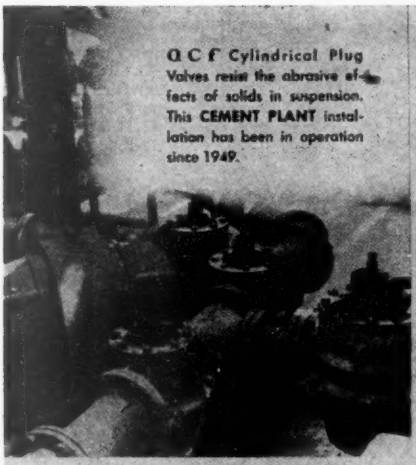
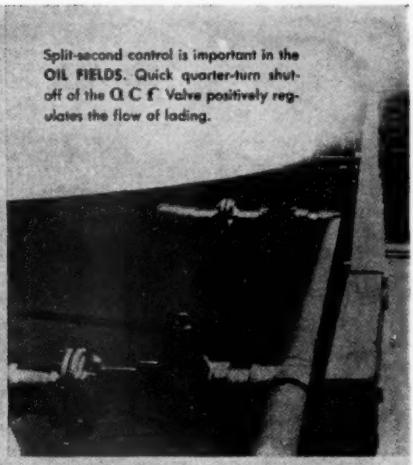
694 Fischer Road, Hatboro, Penna. LA-1005

18 YEARS EXPERIENCE SUCCESSFULLY MANUFACTURING CHLORINE FLOW METERING EQUIPMENT

PROOF OF QUALITY

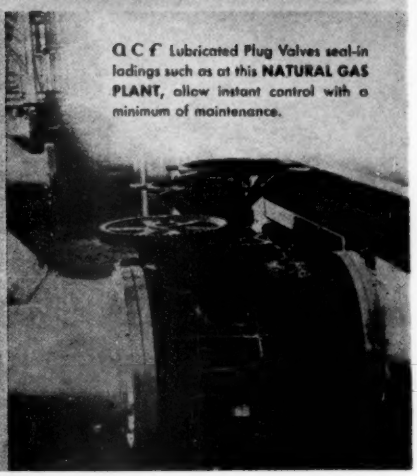


acf Cylindrical Plug Valves resist the abrasive effects of solids in suspension. This **CEMENT PLANT** installation has been in operation since 1949.



Split-second control is important in the **OIL FIELDS.** Quick quarter-turn shut-off of the acf Valve positively regulates the flow of lading.

In **SEWAGE DISPOSAL PLANTS,** Full Pipe Area assures unobstructed flow. The shearing effect of the acf Cylindrical Plug quickly eliminates stoppages.



acf Lubricated Plug Valves seal-in ladings such as at this **NATURAL GAS PLANT,** allow instant control with a minimum of maintenance.

acf

Representatives in 50 Principal Cities

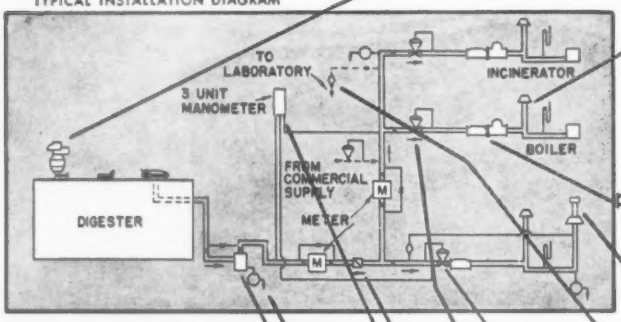
CYLINDRICAL PLUG VALVES

FULL PIPE AREA

PLUG VALVES

Write for descriptive Catalog 4-S1 to ACF Industries, Incorporated, Valve Division, 1501 E. Ferry Avenue, Detroit 11, Michigan.

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 —Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

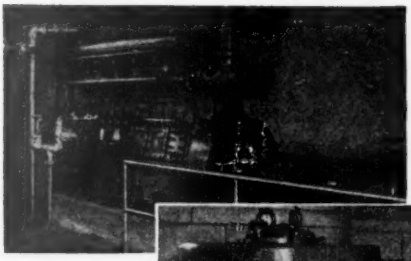
COMPTON, CALIFORNIA, U. S. A.

S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

Long-wearing

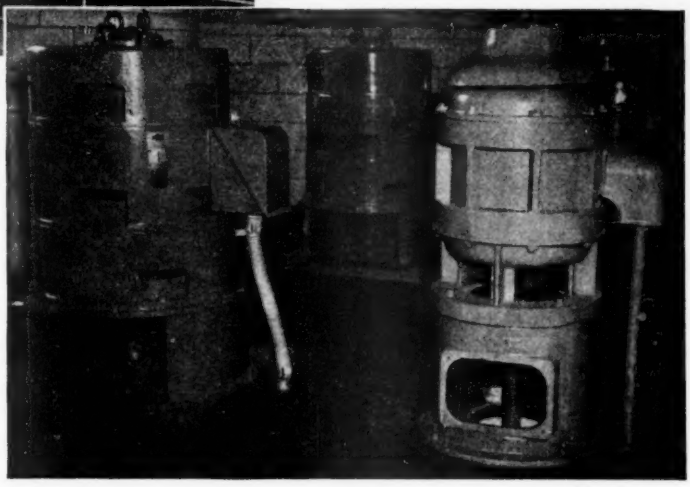
INERTOL® PAINTS

specified in Elmira, New York, plant



Sparkling protection was afforded this big gas engine at Elmira's Sewage Treatment Plant with Inertol Glamortex® Enamel. All surfaces were first primed with Inertol Quick-Drying Primer No. 626, a top-quality rust inhibitor which provides a perfect bond for the finish coats.

Easy maintenance of this battery of sludge pump motors was achieved with Glamortex Enamel, Battleship Grey No. 331. This easy-to-clean paint stands up for years under abrasion, oil spillage and frequent cleaning.



Inertol Paints meet precise requirement of plant designed by Nussbaumer, Clarke & Velzy

For top protection, Elmira's Sewage Treatment Plant needed paints that would provide lasting durability, elasticity and chemical resistance. That's why Inertol coatings were chosen for this modern plant which was designed and constructed under the supervision of Nussbaumer, Clarke & Velzy. Inertol meets all these exacting requirements. For 18 years, the city of Elmira has been using hundreds of gallons of Inertol Paints—bituminous coatings as well as colored enamels.

All over America, thousands of Inertol-painted installations speak for this paint's economical and efficient superiority. Whatever your specific painting problem is, there's sure to be an Inertol coating to solve it. Ask to have your local Inertol Field Technician call. Or write for our free "Painting Guide." It's prepared especially for Consulting Engineers, Specification Writers, Design Engineers and Plant Superintendents. Send for this valuable booklet today.

INERTOL CO., INC.

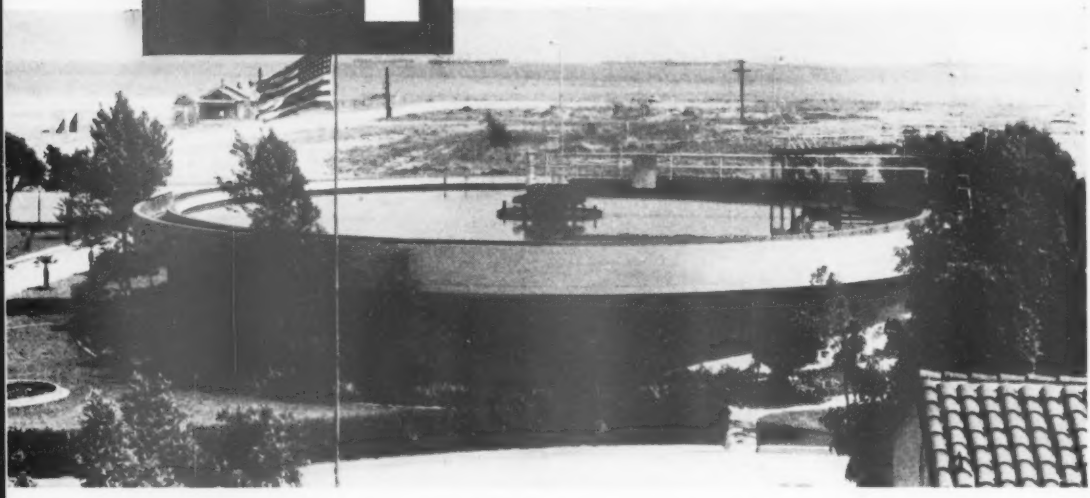
482 Frelinghuysen Ave.
Newark 5, N. J.

27H South Park
San Francisco 7, Calif.

"not one cent for main bearing repair!"

with

Improved Clarification



TROUBLE FREE CLARIFICATION as at the City of Los Angeles' Terminal Island plant, is not surprising. In more than 155 Process Engineers Inc. clarifier installations in the past eight years, there has not been a single main bearing failure . . . not one cent spent for repairs!

Performance records like these prove the wisdom of investing in the superior design and construction quality of PEI equipment.

Quality shows—in Process clarifiers, for example—in the drive unit bearings . . . anti-friction, precision-made by bearing specialists, with a capacity four to six times the applied load! In the adjustable overload alarm and motor cut-off . . . vapor-proof, gas and water tight in a cast brass housing. Advanced design is evident in the improved feedwell that minimizes short-circuiting. In the arms and blades that sweep the tank bottom twice per revolution, and eliminate large accumulations on structural parts.

". . . *Not one cent for repairs*" reminds again that you get exactly what you pay for—and that Process Engineers equipment for modern sewage plants delivers the most.

Request Bulletin # 117
illustrating equipment for
Grit Separation
Flotation
Clarification
Pre-aeration
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Industrial Wastes
Water Purification
or submit your problem for the handling of suspended solids in liquids.

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Make use of the Unique Advantages of WELSBACH OZONE in Solving Them

If the presence of phenolic compounds in industrial waste is a problem to you and your community . . . and complete destruction is required . . . you should investigate—right now—the economical and dependable solution of that problem by low-cost Welsbach Ozone treatment.

Investigations have shown that chemical oxidation with Welsbach Ozone can provide an *economical* and *complete* answer to the problem of removing phenols from industrial waste.

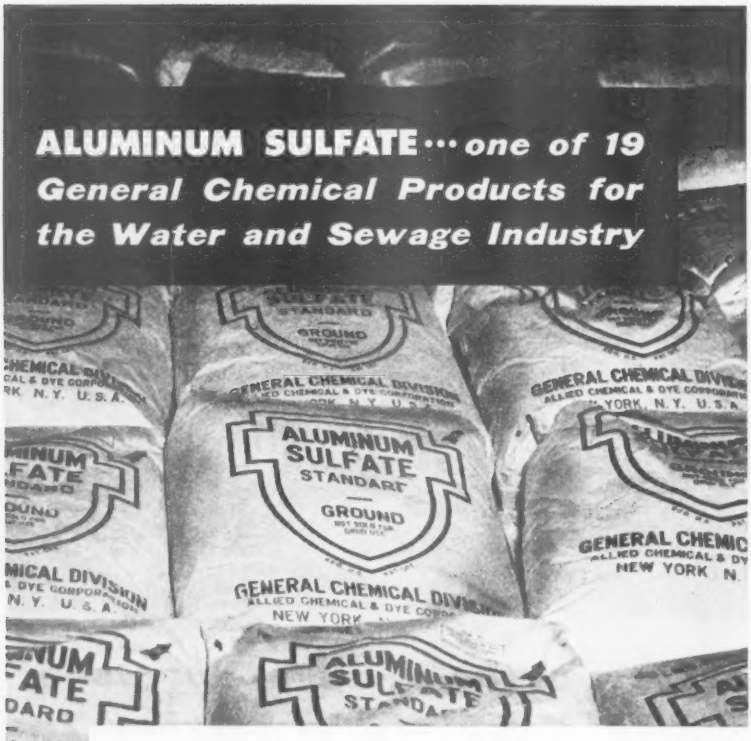
In addition to its relatively low cost, Welsbach Ozone treatment offers other unique and important advantages:

1. Ozone-phenol reaction is instantaneous. End products are non-toxic. Objectionable tastes and odors do not reappear when water is chlorinated.
2. Welsbach Ozone gives collateral reduction in color, B.O.D. and C.O.D.
3. A Welsbach Ozone plant can be operated on a batch treatment or on continuous basis and can be made fully automatic. Ozonators and treatment vessels require very little space.
4. Welsbach Ozone is generated where it is used. No procurement problems. No freight, storage or materials handling expense.
5. Maintenance costs are negligible. And since the only raw materials needed are electricity and air or oxygen, operating costs are constant and predictable.

. . . but, most of all, Welsbach Ozone is economical, convenient and dependable. Write today for information and, if you wish, indicate the nature of your problem. The Welsbach Corporation, Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

Investigate **WELSBACH** OZONE

LOW COST • DEPENDABLE


ALUMINUM SULFATE ··· one of 19
General Chemical Products for
the Water and Sewage Industry
ALUMINUM SULFATE STANDARD GROUND
GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
NEW YORK, N. Y. U. S. A.

Among the many "Basic Chemicals for American Industry" which General Chemical produces, the following are widely used by the Water Industry. For your requirements, write or phone the nearest General Chemical office listed below.

COAGULATION
Aluminum Sulfate, Standard
Aluminum Sulfate, Liquid
Ammonium Alum
Potassium (Potash) Alum
Sodium Silicate

FLUORIDATION
Sodium Fluoride
Sodium Silicofluoride

DECHLORINATION
Sodium Sulfite
Sodium Bisulfite, Anhy.
Sodium Thiosulfate

BOILER WATER
Sodium Sulfate, Anhy.
Disodium Phosphate, Anhy.
Trisodium Phosphate
Sodium Silicate
Sulfuric Acid

CORROSION CONTROL
Sodium Silicate
Tetrasodium Pyrophosphate

For Other Uses:
Glauber's Salt, Crystal
Aqua Ammonia
Hydrochloric Acid (Muriatic)
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Allied Chemical

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for every job
Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.

IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

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IOWA FLAP VALVES—all iron; can be furnished with bronze hinge bolts or fully bronze mounted—including bronze bolts, flap ring and seat ring—when required.

CLOW HYDROSTATIC RELIEF VALVES — commonly used in bottom of concrete tanks to prevent ground water from floating the tank. Close-grained cast iron body and lid; lead seat ring and lid ring. Cast iron grate in bottom prevents foreign matter from entering tank.

IOWA PLUG DRAIN VALVES—either rising or non-rising stem type. High strength cast iron bodies; bronze stem, operating nut, disc ring and seat ring; rustproof steel bolts and nuts. Handwheels, extension stems, plain or indicating floor stands if required.

IOWA SLUICE GATES—can be used in lines having both seating and unseating pressures. High strength cast iron, bronze mounted, with solid bronze adjustable wedges. Can be equipped with cylinder or motor unit for automatic operation.

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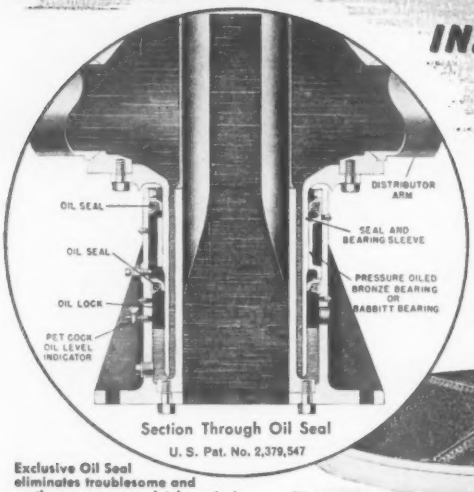

Section Through Oil Seal
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Exclusive Oil Seal eliminates troublesome and costly mercury, completely protects bearing surfaces, and will not blow out under excessive heads.

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EFFICIENT CONTINUOUS OPERATION

MINIMUM MAINTENANCE

Reaction Drive and Positive Drive
ROTARY DISTRIBUTORS

Hundreds of installations have proved the advantages of *American* Rotary Distributors. This approval by consulting engineers is based on economy of initial cost, structural strength and durability, superior liquid distribution, applicability to wide ranges of flow and available head, and minimum maintenance. Inherent design features reduce hydraulic-head losses to a minimum, and provide for maximum utilization of available hydraulic head in performance of useful work. *Every oil seal unit installed has given excellent, trouble-free service!* Available in a wide range of both Reaction-Drive and Motor-Driven Positive-Drive Distributors to meet all variations of actual field conditions—for rapid or standard rate waste filters, sand filters, or for water aeration. *Utilize the experience of American engineers.*

For helpful data and design details, write for Technical Supplement RD

On exhibit at Annual Convention, Federation of Sewage & Industrial Wastes Associations, Cincinnati, Oct. 11-14

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Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

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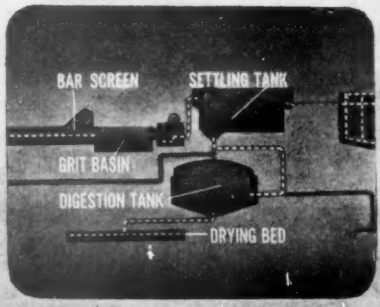
"CLEAN WATERS"



THE 1954 edition of G.E.'s dramatic color movie to be premiered at October meeting of the FSIWA

General Electric's full color, sound motion picture, **CLEAN WATERS**, which forcefully illustrates the dangers of water pollution, has been completely re-filmed and brought up-to-date. This public-service film points out the dangers to home, farm, and industry arising from polluted water sources, and outlines a permanent solution to the problem—modern waste treatment.

The original film—first shown seven years ago—was viewed by more than one million people throughout the world and was nationally acclaimed by community and industrial organizations who utilized it in launching campaigns to clean up their water sources.

This dramatic new edition of **CLEAN WATERS** can be an indispensable tool in helping you promote the increase of adequate sewage and waste treatment. It will be premiered at the annual meeting of the Federation of Sewage and Industrial Wastes Associations in Cincinnati, October 11–14, as part of the official program. Be sure to see it. General Electric Company, Sect. 666–87, Schenectady 5, N. Y.

More Power to America

GENERAL ELECTRIC

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Carter Floating Covers

FOR BETTER DESIGN AND ACCURATE CONSTRUCTION

The excellent design and accurate construction of Carter sludge digestion equipment has earned the praise of Engineers and Field Men everywhere. Carefully laid-out and stress-analyzed . . . then pre-assembled and match-marked at the factory . . . every Carter Floating Cover (such as the 100 ft. unit shown above) is built for swift, troublefree erection in the field — and perfect operation in the plant.

Add to this, the Carter Heat Exchanger with its exclusive system of jacketed piping. Here's a heating system acclaimed, by many, as the most efficient yet devised for the temperature-sensitive digestion process. Plant Operators particularly like the freedom of arrangement between sludge tubes and boiler . . . giving maximum convenience in location and greater accessibility in cleaning.

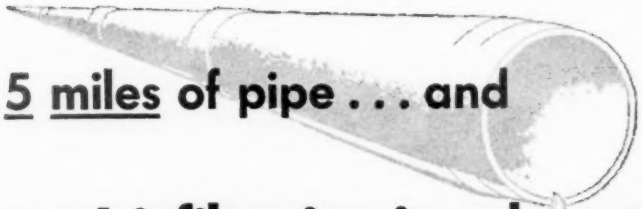
And, of course, there's a complete line of Underwriter's Approved gas utilization equipment for any system of balanced digestion.

Engineers have discovered that among the many advantages in specifying Carter equipment is the excellent service that goes with it. These men know that every Carter sludge digestion system includes not only the finest in equipment of its type . . . but also an interest by the Ralph B. Carter Company that extends beyond the sale to successful installation and operation.

Ralph B. Carter Company

210 ATLANTIC STREET, HACKENSACK, NEW JERSEY

Write Today For information or assistance in solving your sludge digestion problems. There's no obligation, of course.



5 miles of pipe . . . and total infiltration is only a trickle . . .

. . . with Transite® Sewer Pipe

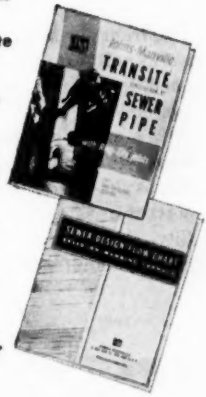
THE REDUCTION of ground-water infiltration brought about by the Ring-Tite® Joint—now standard on all sizes of Transite® Sewer Pipe—can lead to a number of cost-saving results.

For example, on one recently installed Ring-Tite System using 28,540 feet of Transite Sewer Pipe, in diameters of 6 through 18 inches, the infiltration per inch of diameter, per hour, per mile of pipe, came to a mere 0.85 gal. This low infiltration (including that from manholes and connections to house sewers) was achieved despite the fact that a considerable portion of this installation was below the prevailing ground water table. (For specification purposes, an infiltration allowance of 10 gallons per inch of diameter, per hour, per mile of pipe, may be used with Transite Sewer Pipe.)

Obviously, such minimum ground-water infiltration helps reduce the load on treatment plants, cuts down on treatment costs, and conserves plant capacity for future expansion needs. This reduced infiltration plus Transite's high flow capacity (Manning's N=.010) often permits the use of smaller diameter pipe for new installations.

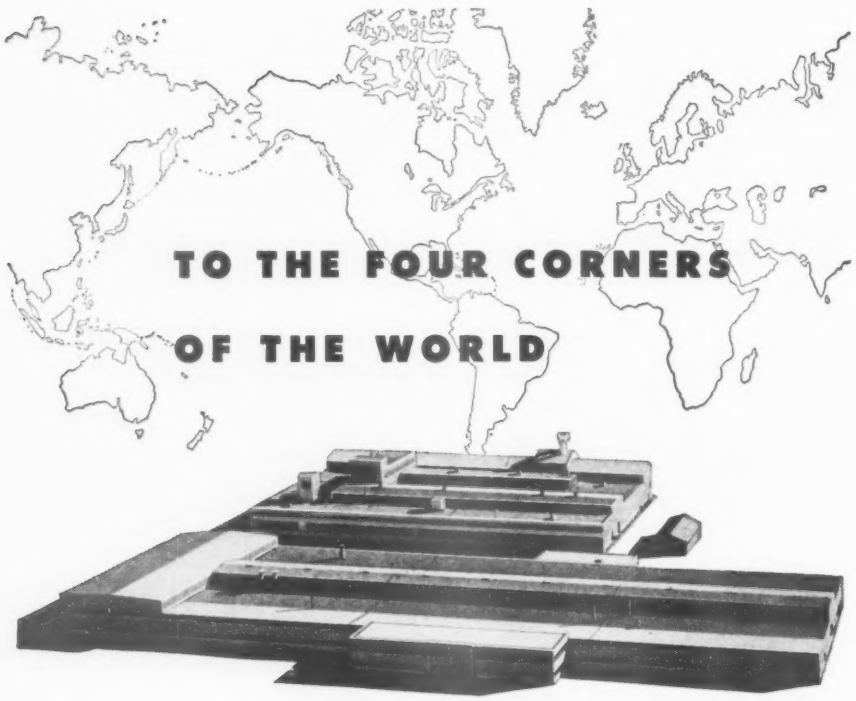
For further information on how this Ring-Tite Joint, used with corrosion-resistant, asbestos-cement Transite Pipe can help reduce your sewage costs, write Johns-Manville, Box 60, New York 16, N. Y. Ask for folders TR-103A and TR-94A.

Tells more about Transite asbestos-cement Sewer Pipe with Ring-Tite joints—for non-pressure service. Ask for Brochure TR-103A.



Helpful to Engineers— Sewer Design Flow Chart Based on Manning Formula. Ask for Brochure TR-94A.

Johns-Manville TRANSITE SEWER PIPE



Aerial view of the Kansas City, Kansas Works, Fairbanks, Morse & Co., 3601 Kansas Avenue.

...from Kansas City

Yes, from our new, modern-as-tomorrow works at Kansas City, we serve the world's need for pumps, engines and oil field equipment.

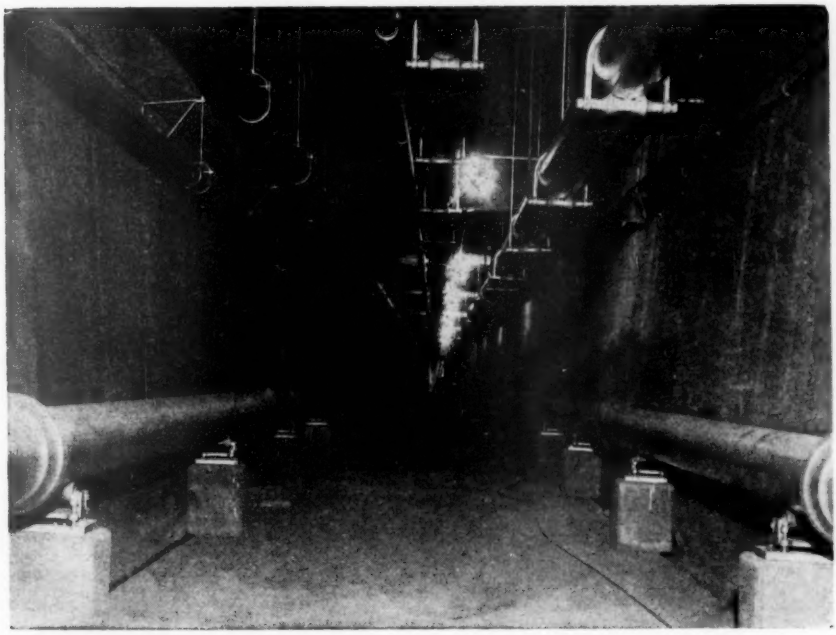
As a major supplier of pumping equipment, it is particularly suitable that Fairbanks-Morse be located at an important crossroads of the world... Kansas City. In this new plant 190,000 square feet of manufacturing space and a complete foundry occupying 150,000 square feet are devoted to bringing better service to our customers all over the world.

Modern manufacturing, development and testing equipment backed by the design, engineering and production skills of highly trained personnel combine to produce products of unmatched quality... in performance, durability, economy. Fairbanks, Morse & Co., Chicago 5, Ill.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY • RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS



AMERICAN Cast Iron Pipe

For Sewage Treatment Plants

AMERICAN pipe serves equally well beneath crowded city streets or in sewage treatment plant installations like the one shown above. AMERICAN'S unexcelled foundry facilities and highly trained and experienced organization prove exceedingly helpful on sewage disposal work.

AMERICAN pipe is conveying sewage, water, gas, crude oil, gasoline, sour naphtha, salt brine and chemicals under operating pressures ranging from a few pounds to the square inch up to pressures in excess of 100 pounds gas and 500 pounds liquid.

AMERICAN pipe has the lasting strength that enables it to survive continued corrosive attack, year after year, and to keep on giving the same dependable, economical service as the day it was installed. It is manufactured under rigid specifications in diameters 2-inch through 48-inch.

Refer your next piping problem to AMERICAN and utilize both our extensive manufacturing facilities and our nearly half a century of experience in furnishing pipe and fittings for water works and for sewage disposal plants.

Let us assist you by taking off lists of material and submitting a price on pipe and fittings for your next job.

Write for free literature. Address the AMERICAN office nearest you.

AMERICAN CAST IRON PIPE COMPANY

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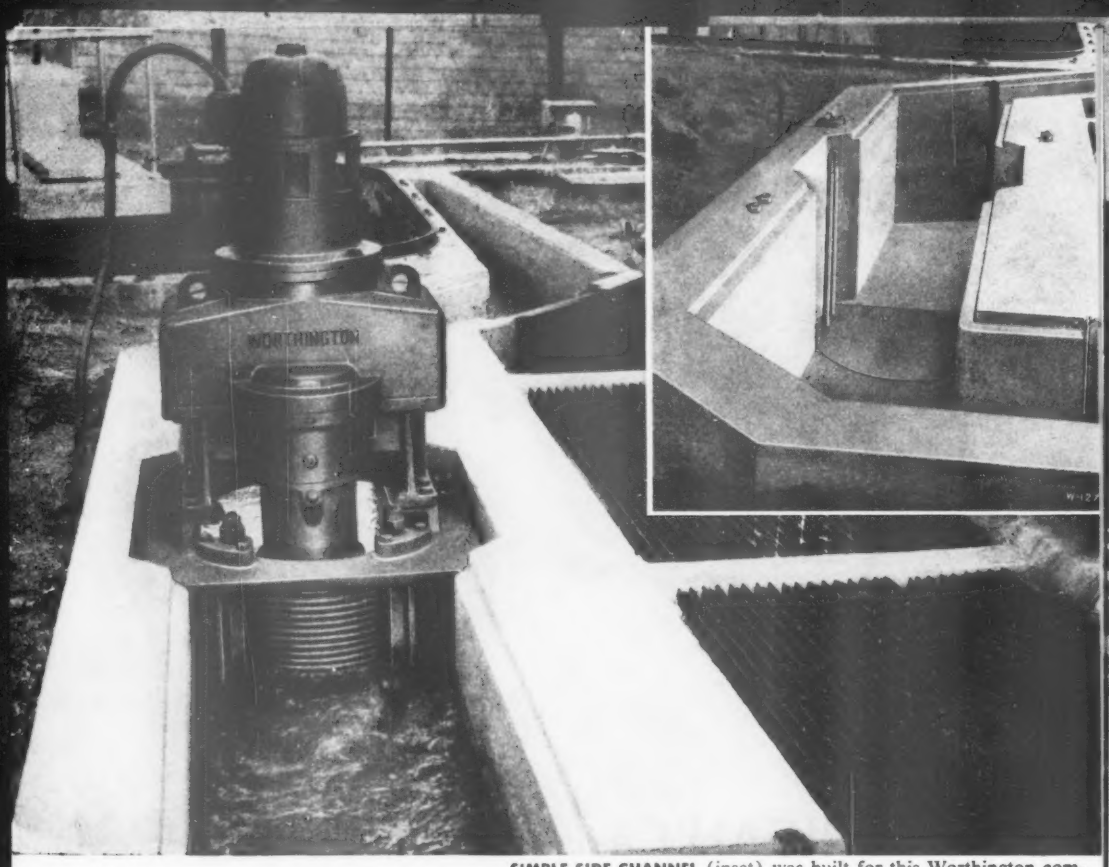
Dallas Houston El Paso Pittsburgh Kansas City New York City
Chicago Minneapolis Cleveland Denver Los Angeles San Francisco Seattle



SIMPLE SIDE CHANNEL (inset) was built for this Worthington comminutor at Klamath Falls, Oregon, because Mr. E. A. Thomas, the City Engineer, wanted to use the existing channel as a by-pass.

Low installation cost swings Klamath Falls to Worthington

Since the Worthington comminutor is designed so that raw sewage flows straight through its screen, it's easily installed in a straight rectangular sewage channel.

Result? Expensive masonry work is not needed, which makes for simplified, low-cost installation.

This was an important factor in the selection of a Worthington 25C6 comminutor as part of recent improvements at the Klamath Falls, Oregon, Sewage Treatment Plant.

This comminutor, installed downstream from a grit chamber and upstream from a clarifier, was lifted directly from its packing crate and set right in the channel in a minimum of time.

Easy-to-remove cutter racks for occasional sharpening and the built-in flood protection provided by a mercury seal are other advantages of the Worthington comminutor.

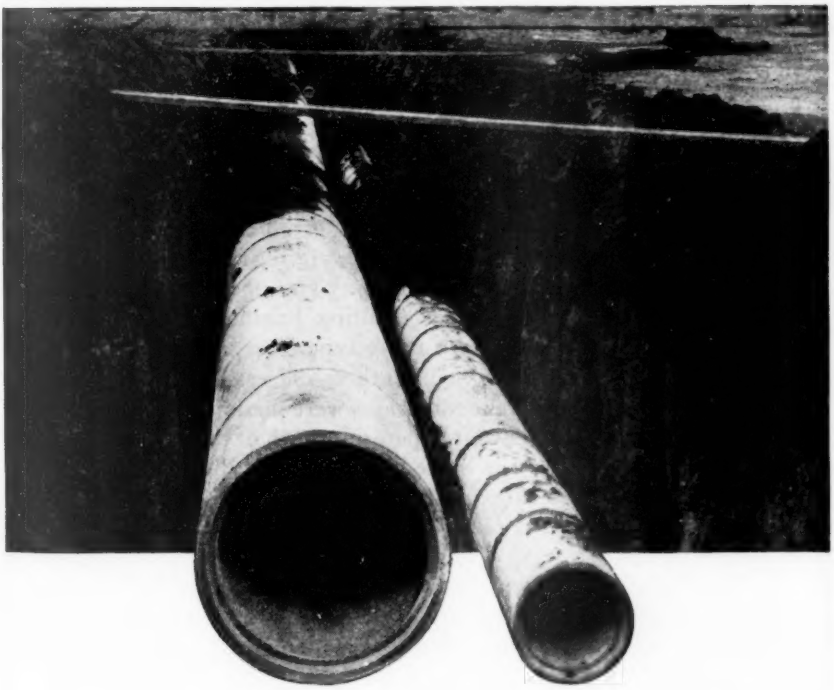
Get all the facts and figures on the rugged Worthington comminutor. Check with your nearest Worthington district office. Or write today for new engineering manual on comminutors, W-317-B17. Worthington Corporation, Public Works Division, Harrison, N.J.

W.4.5

WORTHINGTON

ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY

Water Works Pumps • Sewage Pumps • Comminutors • Vertical Turbine Pumps • Vacuum Pum



Storm Water or Sewage... you can solve your sewer problems with *CONCRETE PIPE*

Whether you plan a storm sewer, sanitary sewer or combination of both in one trench, as in the photo above, concrete pipe will solve your problem. You get better, longer, more economical service from concrete pipe sewers because:

1. Concrete pipe's great strength resists severe impact and sustains heavy overburdens.

2. Concrete pipe's uniformly dense structure along with its watertight joints is assurance of minimum infiltration and leakage in the lines.

3. Concrete pipe's smooth interior finish resists the wearing action of suspended abrasive matter and provides maximum hydraulic capacity.

4. Concrete pipe's unusual durability means long service. Many concrete pipe sewers have been serving 60, 80, 100 or more years.

5. Concrete pipe's first cost is moderate, its service life is extra long, its maintenance cost is extra low. The result is *low-annual-cost* sewer service. This is the only true measure of sewer line economy.

AMERICAN CONCRETE PIPE ASSOCIATION

228 NORTH LA SALLE STREET, CHICAGO 1, ILLINOIS

In Appreciation

IN JUNE, 1946, Walter Sanderson and the writer, along with some hopeful Stockholders, established this business. We made our first sludge dewatering installation at Liberty, New York, in July, 1949. The operation was a success, and a number of Consulting Engineers were encouraged to utilize the coil spring type filter in connection with plants being designed in their offices. From 1949 through 1952, 21 more installations were made in the East, and as these units went into operation, each of them worked with a success that was indeed gratifying to all of us here, and led to (1) the construction of suitable manufacturing facilities for production of these machines and their auxiliaries, and (2) setting up a sales organization to work with Engineers to apply the coil spring type filter, now known as the "Coilfilter," for solution of their sludge dewatering problems. During the past two years 48 more units have been sold, of which a considerable number have gone into operation, again with unqualified success.

The writer is desirous of expressing his thanks to the Sanitary Engineering Profession for their acceptance and use of our equipment. We are mindful of our obligation to these Engineers and to the Operators and will maintain our standards.

In closing, let me say that when you are in the vicinity of Peapack, please stop in and visit with us. The manufacture of this equipment is most interesting, and we will be glad to see you.

Respectfully,

T. R. Komline

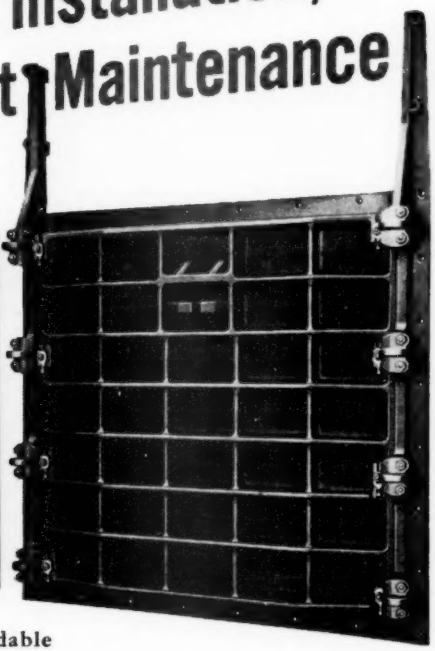
KOMLINE-SANDERSON
ENGINEERING CORPORATION

MANUFACTURERS OF THE COILFILTER

PEAPACK, NEW JERSEY

Completely Interchangeable Components Mean Fast Installation, Low-Cost Maintenance

with CHAPMAN *Standard* SLUICE GATES



Fast installation, dependable trouble-free operation and low maintenance costs explain why Chapman *Standard* Sluice Gates are specified everywhere.

Interchangeable components make matchmarking or field alteration unnecessary, so installation is always quick and simple.

Uniform construction, from designs that have been developed in over seventy-five years' experience, means parts fit accurately and operate smoothly under the heaviest unbalanced loads.

Maintenance is simple, too, because repair or replacement parts, when and if needed, are made to the same uniform accuracy for perfect fit without extra work.

Specify Chapman *Standard* Sluice Gates on your job. A wide range of catalogued sizes and designs, all with any type of control you want — manual, electrical, or hydraulic. Write now for Catalog No. 25.

The Chapman Valve Manufacturing Company
INDIAN ORCHARD, MASSACHUSETTS

Count costs in pennies

Thirty cents per dry ton of sewage sludge incinerated. That is the average annual maintenance cost of a typical Nichols Herreshoff dryer-incinerator over years of continued, dependable service.

Only the Nichols Herreshoff multiple hearth furnace combines proved low operating cost and rugged construction with dual-purpose adaptability to burn all types of sludge to a sterile ash or dry it to a product excellent for soil conditioning.

The Nichols Herreshoff sludge dryer-incinerator is a development of Nichols world-wide multiple hearth experience in the chemical, metallurgical, cement and process industries. Thousands of these furnaces are now in operation.

Nichols Herreshoff

Multiple Hearth Dryer-Incinerators

Nichols Engineering and Research Corp.

70 Pine St., New York 5, N. Y.

1637 N. Illinois St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
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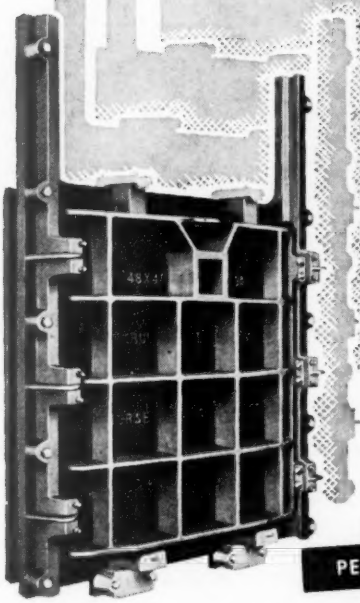
Pekrul Grows



To keep pace with the ever increasing demand for PEKRUL GATES over half a century, MORSE BROS. MACHINERY has just completed an extensive modernization program. The installation of many new machines and facilities, an increased engineering staff, and complete, new, custom re-tooling specifically for PEKRUL GATE production means...

modern design and superior engineering service...

even faster PEKRUL GATE deliveries to you...

PEKRUL GATE DIVISION

MORSE BROS. MACHINERY
DENVER, COLORADO

MANUFACTURERS OF PEKRUL GATES FOR

Flood Control · Sewage Disposal · Rearing Ponds · Recreation Pools
Levees · Reservoirs · Irrigation · Cooling Towers · Pumping Plants
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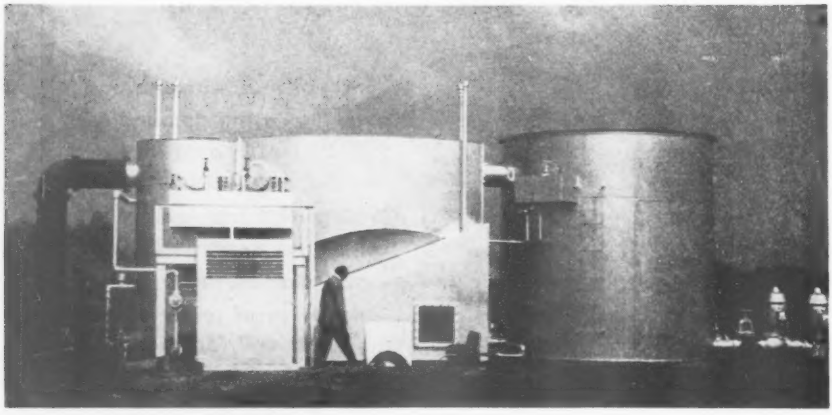
GALE WASTE WATER TREATMENT SYSTEM INSTALLED AT THE DIESEL SHOP OF A LARGE RAILROAD IN THE MIDWEST



Gale Waste Water Treatment System removes oil, grease, grit and sand from the waste water coming from diesel shops, wash racks, fueling stands and sand-operated equipment. Normal flow rate through Gale System is 2,000 g.p.m., with provision for storm-water by-pass. After this water is cleansed of impurities, it flows to a cooling pond. Railroad uses this cooling pond water for industrial purposes. System eliminates pollution and conserves the water for continuous use.

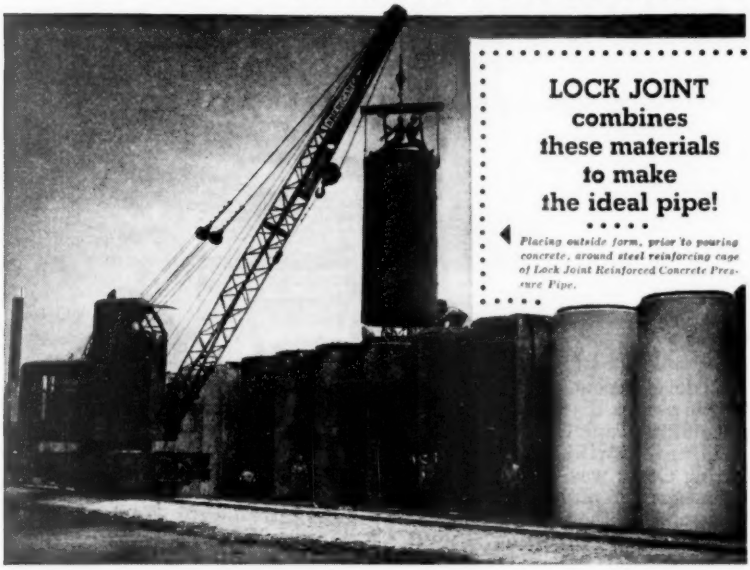
GALE OIL SEPARATOR CO., INC.

Murray Hill 4-1890

GOSCO
Trade Mark
Reg. U. S. Pat. Off.

53 Vanderbilt Avenue
New York 17, N. Y.

There's no substitute for CONCRETE and STEEL!



LOCK JOINT combines these materials to make the ideal pipe!

Placing outside form, prior to pouring concrete, around steel reinforcing cage of Lock Joint Reinforced Concrete Pressure Pipe.

CONCRETE, with its proven qualities of durability, non-corrosion, resistance to electrolytic action, and high compression strength is combined, by Lock Joint, with steel's toughness, resilience and high tensile strength to make a pipe that retains the best qualities of both—non tuberculance, high structural strength and long life with little or no maintenance. Dense concrete affords complete protection for the quality reinforcing steel. Both materials are carefully calculated to meet your pressure needs with a wide factor of safety. The Lock Joint Pipe Company's Rubber and Steel Joint is extremely watertight and, at the same time, flexible.

For superior strength, carrying characteristics and trouble-free operation, let Lock Joint supply your pipe needs in sizes 16" and larger.

LOCK JOINT PIPE COMPANY

Established 1905

P. O. Box 269, East Orange, N. J.

PRESSURE PIPE PLANTS: Wharton, N. J., Turner, Kan., Detroit, Mich., Columbia, S. C.

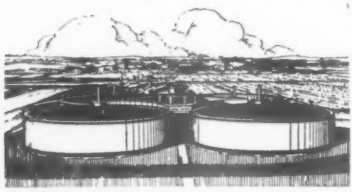
SEWER & CULVERT PIPE PLANTS:
Casper, Wyo. • Cheyenne, Wyo. • Denver, Col. • Kansas City, Mo. Kennett Square, Pa. • Valley Park, Mo. • Chicago, Ill. • Rock Island, Ill. • Wichita, Kan. • Kenilworth, N. J. • Hartford, Conn. • North Haven, Conn. • Tucumcari, N. Mex. • Oklahoma City, Okla. • Tulsa, Okla. • Beloit, Wis. • Hato Rey, P. R. Ponce, P. R. • Caracas, Venezuela • Wholly Owned Subsidiary, Great Lakes Pipe Co., Plants: Buffalo, N.Y. • W. Henrietta, N.Y.

LOCK JOINT Reinforced Concrete PRESSURE PIPE

SCOPE OF SERVICES—*Lock Joint Pipe Company specializes in the manufacture and installation of Reinforced Concrete Pressure Pipe for Water Supply and Distribution Mains 16" in diameter or larger, as well as Concrete Pipes of all types for Sanitary Sewers, Storm Drains, Culverts and Subaqueous Lines.*

New developments in "controlled digestion"

A STATEMENT OF POLICY



In the development of controls for the separate sludge digestion process, the Pacific Flush Tank Company has been a leading contributor. The P.F.T. Floating Cover was developed to provide means for positive submergence of the scum in the seeding liquor and allow safe gas utilization. P.F.T.'s development of external heating of recirculated digester contents and raw sludge assures the maintenance of constant optimum digester temperatures. And more recently the development of the P.F.T.-Pearth Gas Recirculation System provides a positive means for the rapid dispersion and elimination of scum accumulations.

Our Policy is Clear — With our many contributions to the basic knowledge of the sludge digestion process, it has always been our policy to point out the advantages of closely controlling all factors affecting digestion. With effective controls, operational difficulties are eliminated and successful digestion results—the production of an inoffensive sludge of uniform concentration suitable for ultimate disposal.

We will continue to advocate the use of established design criteria for digestion capacity as formulated by consulting engineers and State Boards of Health. We feel that these criteria are developed to take into consideration practical plant operating procedures and future requirements. These criteria cannot be based solely upon results of pilot plant studies which require careful control by staffs of highly skilled technicians.

The introduction of the P.F.T.-Pearth Gas Recirculating System provides an economical means of dispersing scum accumulations, making the total digester volume available for effective digestion. There is no *mysterious* action in the operation of any gas recirculating system. It is merely a *mechanical* action which aids the normal biological activity by breaking up the scum so that it can be digested.

To those interested in sewage and waste treatment, Pacific Flush Tank Company will continue to offer straightforward information about all of its equipment and new developments.

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **September, 1954** **Number 9**

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Sewage Works

ACTIVATED AERATION AT THE WARDS ISLAND SEWAGE TREATMENT PLANT *

By A. H. Chasick

Civil Engineer (San.), Department of Public Works, New York City, N. Y.

Because of the magnitude of the problem of treating New York City's sewage, continual efforts are made to develop new treatment procedures which will produce improved results and significant economies in both construction and operating costs. Thus, in the field of aeration, the step aeration activated sludge and the modified aeration processes have been developed and put to use.

During January 1953, some work was done at the Wards Island plant to test the relative merits of straight sewage aeration *versus* the modified aeration process. Comparing plain aeration with aeration of sewage in the presence of return modified aeration solids, it was obvious that the very small quantity of return solids inherent in the modified aeration process was responsible for marked increases in removal. The question then arose as to what advantages could be realized by substituting a similar small quantity of standard activated sludge for the modified aeration solids.

One aeration battery at the Wards Island plant, employing the step aeration process, was producing some 17 dry tons of activated sludge culture per day. These solids, of proven high clarifying capacity, were being wasted to thickening tanks prior to disposal. A constant supply of activated sludge was thus available for a plant-scale experiment to determine whether these solids could again be used to clarify sewage.

Description of Process

One such process employing this concept was visualized in the form shown in Figure 1. An activated sludge unit, either conventional or step aeration, is operated in the usual manner except that the excess activated sludge solids are transferred to another unit to exploit the treatment potential of the culture. In the second unit, primary effluent is aerated in the presence of this small quantity of transferred activated sludge. The aeration tank effluent is settled in final tanks, the clarified liquid overflowing as final effluent. The settled sludge, comprising the original activated culture plus the solids removed by it, is then normally withdrawn for thickening, although the layout allows for the return of sludge to the aerators. It was thought that in the operation of this process, air requirements would be comparable to those of modified aeration and that effluent quality might be somewhat better. Furthermore, since solids are not recirculated through the system, the process should exhibit the biological stability of straight sewage aeration. This process, comprising the re-use of activated sludge, has been named "activated aeration."

Layout of Wards Island

The Wards Island plant was easily adapted to the use of activated aeration because of its division into separate

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

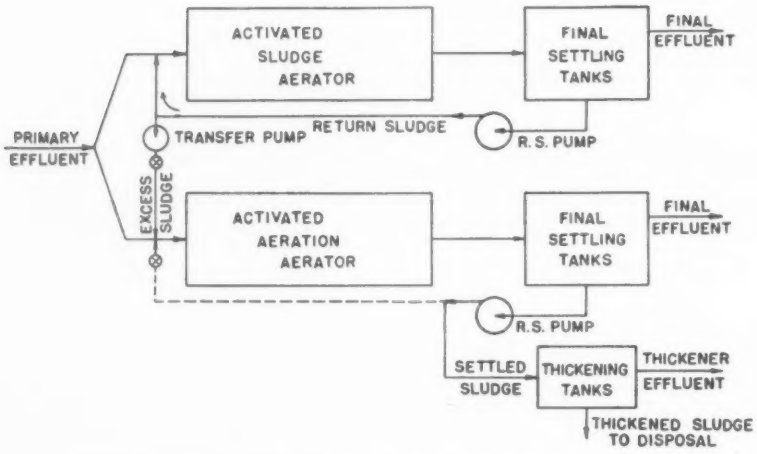

FIGURE 1.—Typical flow diagram of activated aeration operation.

aeration batteries, as shown in Figure 2. The plant, which was designed to treat 180 m.g.d. of sewage, provides for 1.2 hr. of preliminary sedimentation, 5.6 hr. of aeration, based on the design flow plus 25 per cent return sludge, and a final tank overflow rate of 740 g.p.d. per square foot. The secondary system is divided into four batteries, each having four aeration and eight settling tanks. Each battery has its own return and excess sludge pumps and sludge thickening facilities and thus acts as a separate secondary treatment plant.

The aeration tanks have been adapted for step aeration by providing means for adding primary effluent at the quarter and three-quarter points. The final tanks, which originally received aerator effluent from a center distribution conduit, were altered to admit that flow into the near end of the tank. Final effluent overflows into channels at the far end and settled sludge is withdrawn from a center sump. The original influent conduit is available for other uses. These changes to the aeration and final settling tanks have been described in detail by Gould (1).

In each battery, the two final tanks nearest the return sludge pumping station may be used as thickeners, since they are connected to the excess sludge pumps. In a battery operating on the activated sludge process, aerator effluent is wasted to the thickeners. The modified aeration process, however, requires that return sludge be wasted. Thus, in battery D (at left side of Figure 2), the return sludge header has been extended to the former center influent conduit for that purpose. By using these new facilities for the operation of the step aeration and the modified aeration processes, the Wards Island plant has been treating well over 210 m.g.d. of sewage with but one-half the provided aeration tanks.

Application to Wards Island

To apply the activated aeration process to the facilities described, only one additional piece of equipment was required. Some means were needed to transfer excess activated sludge from the step aeration to the activated aeration battery. As shown in Figure 3, battery C was operating on the step aeration process, the primary effluent being added at the quarter and three-

quarter points of the aerators. The mixed liquor channel contained return activated sludge. A portable electric-driven pump of about 1,000-g.p.m. capacity was installed at the entrance to the mixed liquor channel to transfer a small fraction of the return sludge through a valved line to mix with the primary effluent entering battery D. Normal activated sludge operation was continued in battery C. However, instead of wasting aerator effluent to two thickening tanks as was done previously, an equivalent weight of active solids was transferred to battery D for further use there. The concentration of activated sludge in battery C, and consequently its sludge age, was now controlled by the setting of the valve on the new transfer line. Seven final tanks were used for settling aerator effluent and returning sludge and one tank was held in reserve for possible use as a thickener.

The mixture of fresh excess activated sludge and primary effluent entering battery D was aerated in two aeration tanks, for about 2.8 hr. The aerator effluent, averaging 200 to 250 p.p.m. of suspended solids, was settled in six final tanks. Settled sludge was withdrawn, and pumped through the center conduit into two thickening tanks. Ordinarily, no sludge was returned to the aerators. The sewage flow to batteries C and D remained at about the same rate as during previous operation with step and modified aeration, namely 48 and 55 m.g.d., respectively.

Because the process was being operated on a plant scale, with flow limited by hydraulic and other considerations, it was not feasible to explore a wide range of variation in control factors.

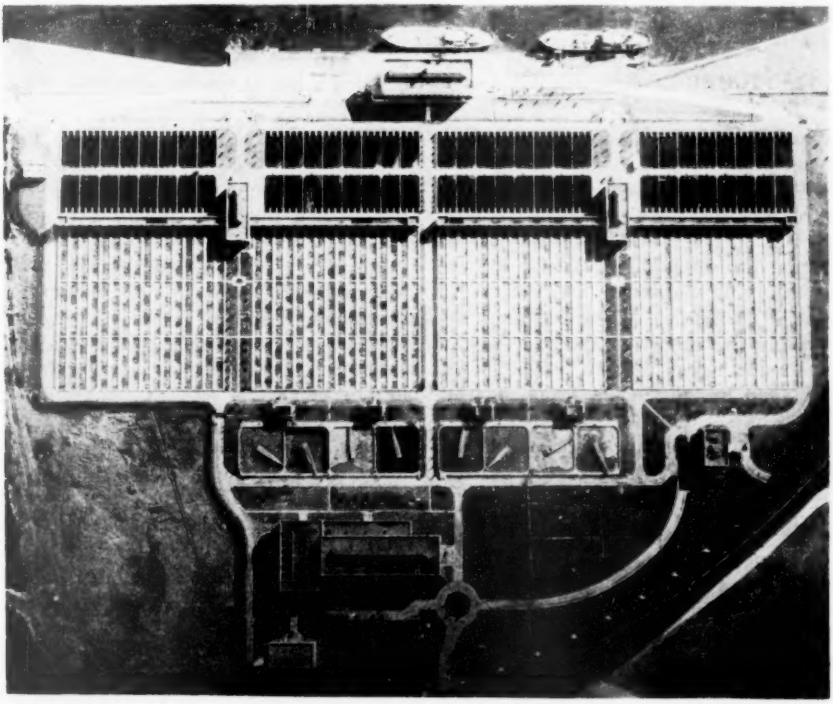

FIGURE 2.—Division of the Wards Island sewage treatment plant into separate aeration batteries facilitated its adaption to the use of activated aeration.

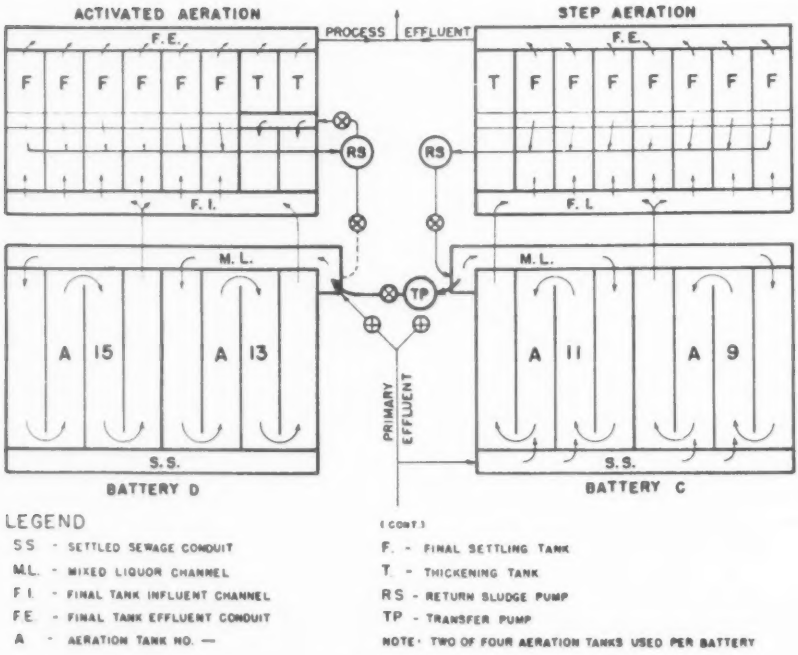

FIGURE 3.—Schematic layout of Wards Island activated aeration operation.

Plant-scale performance could not be readily reproduced in laboratory-scale investigations. A search of the literature was therefore undertaken to ascertain whether any operating or experimental data were available for use in studying activated aeration. An article by Leiner (2) was found describing the theory of the process and discussing some of its possible advantages, but giving no actual operating results. This Wards Island trial appears to be the first successful application of activated aeration.

Operation of Activated Aeration

The new process was started in battery D on February 17, 1953, and has been employed continuously since then. The results of the operation appear in the tables to follow.

Table I describes the characteristics and magnitude of the load applied to the activated aeration battery. A period of more than nine months of operation is covered, with the data presented in the form of monthly averages. The primary effluent averaged 89 p.p.m. of suspended solids and 99 p.p.m. of B.O.D., so that the raw sewage appeared to be of moderate strength. The full scale of sewage temperatures at Wards Island was encountered, temperatures varying from 61° to 78° F.

The activated aeration battery treated an average of 55 m.g.d. of primary effluent. The final tank overflow rate exceeded 1,000 g.p.d. per sq. ft. Of the total flow through batteries C and D together, about 53 per cent was treated by activated aeration. From the standpoint of economy, it is desirable to apportion a high percentage of the flow to the activated aeration battery. However, as the proportion increases, a progressively lower quantity of activated sludge is available for

TABLE I.—Primary Effluent Treated by Activated Aeration

Month (1953)	Flow Treated (m.g.d.)	% Flow[1] to Act. Aeration	Primary Effluent				Temp. (°F.)
			Susp. Sol.		B.O.D. (p.p.m.)		
			(p.p.m.)	(% Vol.)	Total	Filtr.	
Feb.[2]	53	54	95	83	106	49	62
March	54	54	101	80	109	46	61
April	55	54	89	81	101	46	64
May	61	56	92	82	105	46	65
June	57	55	90	81	100	47	74
July	55	52	83	80	85	50	77
Aug.	54	51	76	82	82	50	78
Sept.	51	50	84	82	97	50	78
Oct.	53	52	93	82	106	61	75
Nov.	53	52	89	82	99	61	72
Av.	55	53	89	81	99	51	—

[1] Percentage of total flow to step aeration and activated aeration batteries combined.
[2] Data starting February 17; average includes February as one-third month.

treating these higher quantities of sewage.

The quantity of activated sludge solids transferred to battery D is shown in Table II. This quantity is expressed in the form of p.p.m. added to the flow of primary effluent into battery D and has been calculated on the basis of suspended solids captured from the battery C flow. Thus, 72 p.p.m. of activated sludge were used to treat 89 p.p.m. of suspended solids in the primary effluent. On a monthly basis the activated sludge added to battery D varied from 65 to 80 p.p.m.

The sludge density index of the original activated sludge varied from 0.7 to 1.6, which is within the normal operating range. After re-use of these solids in battery D, the sludge index of the combined settled solids ranged from 1.0 to 1.9, showing a significant increase. Thus, the admixture of fresh raw solids to those transferred improved their settleability.

At the beginning of activated aeration operation, the air supply was maintained at the same rate as was required by the modified aeration process formerly used in battery D. At an air ratio of 0.3 cu. ft. per gallon, high dissolved oxygen concentrations occurred in the aerator effluent. The quantity of air used was progressively reduced until an air ratio of 0.16 cu. ft. per gallon was reached in May without any deterioration of effluent quality. This air flow approximated the minimum required to prevent deposition of solids in the aeration tanks and distribution channels, 70 per cent of the air supply being used in the aerators proper.

When sewage temperature increased sharply in June, it was necessary to increase the quantity of air supplied to the step aeration and modified aeration batteries. At this time, the air rate to battery D was increased. Some dissolved oxygen was present in the aerator effluent throughout the summer. The air ratio for the entire run averaged 0.20 cu. ft. per gallon.

The aerator effluent averaged 225 p.p.m. of suspended solids. Since only 72 p.p.m. of activated sludge were added, these transferred solids removed considerably more than their own weight of material from the sewage, including some previously in the colloidal and soluble form.

Approximately 8 m.g.d. of settled sludge at a concentration of 1,150 p.p.m. of suspended solids were with-

drawn from the final settling tanks and pumped to the thickening tanks. This provided for the moderate overflow rate of 530 g.p.d. per sq. ft. for the thickeners, while the influent concentration was not too high for efficient compaction.

Results of Activated Aeration

The results of more than nine months of operation of activated aeration are given in Table III. During this period, the final tank effluent varied from 23 to 36 p.p.m. of suspended solids, averaging 28 p.p.m. The B.O.D. ranged from 25 to 39 p.p.m., averaging 30 p.p.m. From the beginning, the activated aeration effluent was consistently better than that from the parallel operation of modified aeration. Apparently, the effluent quality was not markedly influenced by temperature and seasonal factors.

During May a test was made of the effect of returning some settled solids from the final tanks to the aeration tanks. There was no significant change in the effluent quality from that secured in April when no solids were returned. Since some impairment in thickener performance occurred at this time, the test was terminated. However, the trial indicated that some solids could be recirculated through the aerators without reducing the stability of the process.

The 8 m.g.d. of settled sludge pumped to the thickening tanks represented a significant portion of the flow treated by activated aeration. It was therefore important that the thickener effluent be of good quality, as it constituted 14 per cent of the process effluent. Furthermore, the thickeners were receiving the waste sludge not only from activated aeration, but also from the accompanying activated sludge battery. Even though these rectangular tanks were not designed for thickening, the thickener effluent was satisfactory, adding but 3 p.p.m. to the suspended solids and 1 p.p.m. to the B.O.D. Including the effect of thickener effluent, the process effluent averaged 31 p.p.m. of suspended solids and B.O.D.

The thickened sludge varied from 2.7 to 3.9 per cent solids having a volatile content of 74 to 81 per cent.

TABLE II.—Activated Aeration Treatment Factors

Month (1953)	Activated Sludge			Air (cu.ft./gal.)	Activated Aeration			
					S.S., Aer. Effl. (p.p.m.)	Settled Sludge		
						Susp. Sol.		Sl. Dens. Index
	Flow to C (m.g.d.)	Added to D (p.p.m.)	Sludge Density Index			(p.p.m.)	(% Vol.)	
Feb.[1]	45	73	0.7	0.32	230	1,350	83	1.3
March	46	80	1.0	0.23	225	1,350	80	1.5
April	47	71	0.9	0.17	225	1,200	79	1.5
May	47	65	0.8	0.16	245[2]	1,300	78	1.1
June	46	69	0.8	0.18	230	1,100	80	1.0
July	50	70	1.6	0.21	215	1,050	78	1.9
Aug.	51	67	1.3	0.21	200	1,000	80	1.5
Sept.	50	77	1.2	0.23	235	1,100	80	1.5
Oct.	48	74	1.1	0.20	225	1,000	81	1.5
Nov.	49	74	1.3	0.21	250	1,050	80	1.6
Av.	48	72	1.1	0.20	225	1,150	80	1.5

[1] Data starting February 17.
[2] Not included in average.

TABLE III.—Treatment Results, Activated Aeration

Month (1953)	Final Tank Effl.			Thickener Effl.		Process Effl.		Thickened Sl.	
	Susp. Solids (p.p.m.)	B.O.D. (p.p.m.)		Susp. Solids (p.p.m.)	B.O.D. (p.p.m.)	Susp. Solids (p.p.m.)	B.O.D. (p.p.m.)	Sol. (%)	Vol. (%)
		Total	Filt.						
Feb.[1]	28	28	19	49	40	31	30	3.0	81
March	24	32	20	45	47	27	34	3.3	75
April	23	29	21	34	29	25	29	3.9	78
May	24	28	19	53	51	28	31	3.5	76
June	28	33	23	42	35	30	33	3.4	76
July	29	25	18	45	30	31	26	3.4	74
Aug.	27	25	18	42	26	29	25	2.9	77
Sept.	30	25	16	56	45	34	28	2.7	76
Oct.	36	39	26	74	70	42	44	2.8	77
Nov.	32	32	23	52	40	35	33	3.4	75
Av.	28	30	20	49	41	31	31	3.2	76

[1] Data starting February 17.

These concentrations were materially higher than was to be expected from the thickening of activated sludge alone and showed the consolidating effect of the fresh raw solids captured. This was most noticeable during June and October, when for brief periods the activated sludge index in battery C dropped to 0.3. During these periods, the thickened sludge concentration was not greatly affected and thickener effluent remained satisfactory.

It can be seen from inspection of Tables I and III that the concentration of thickened sludge was significantly reduced when sewage temperatures became higher. In this connection, sludge blankets in the thickening tanks had to be held at lower depths in order to control effluent quality during these warmer months. Nevertheless, for the entire period of operation sludge concentration averaged 3.2 per cent solids.

Comparison with Modified Aeration

While the north side of the Wards Island plant was devoted to this combination of activated sludge and activated aeration operation, the south half was operating on the modified aeration process. A comparison of the results obtained is given in Table IV.

Inasmuch as activated aeration was conceived as a substitute for modified aeration, it is interesting to compare the results of these two processes, treating the same sewage in about equal quantity in each aeration battery. In spite of the fact that the activated aeration final settling tanks were subjected to a higher overflow rate than those used for modified aeration, the activated aeration effluent was superior, especially with respect to B.O.D. Moreover, this one-fifth reduction in B.O.D. discharge was accomplished using about two-thirds of the air supply required by the modified aeration process.

A further advantage of activated aeration, not revealed in any of the tables, was the stability of the process and its ease of operation. As long as a steady inflow of activated sludge was maintained, a good effluent was produced. At Wards Island, modified aeration now requires precise process control if acceptable removal efficiencies are to be obtained.

However, since activated aeration depends upon an accompanying activated sludge system, this combination should be considered as a unit. The combined step and activated aeration batteries

TABLE IV.—Comparison of Treatment Processes at Wards Island, March–November, 1953

	Modified Aeration	Step Aeration	Activated Aeration	Combined Step and Activated Aeration
Flow treated (m.g.d.)	106	48	55	103
Aeration detention (hr.)	2.8	2.6	2.8	2.7
Air ratio (cu.ft./gal.)	0.31	0.60	0.20	0.39
Final tank overflow (g.p.d./sq.ft.)	930	900	1,050	—
Suspended solids (p.p.m.):				
Aerator effluent	160	1,020	225	—
Return sludge	870	4,100	1,150[1]	—
Sludge density index	2.0	1.1	1.5	—
Thickened sludge solids (%)	4.2	—	3.2	3.2
Process effluent (p.p.m.):				
Suspended solids	35	7	31	20
B.O.D.	39	6	31	19
Filtrate B.O.D.	24	3	20	12
Removal efficiency (%):[2]				
Suspended solids	76	95	79	86
B.O.D.	69	95	75	85

[1] Settled sludge to thickener.
[2] Removal efficiency based on raw sewage; 145 p.p.m. suspended solids, 123 p.p.m. B.O.D.

accomplished an over-all removal, with respect to raw sewage strength, of 86 per cent of the suspended solids and 85 per cent of the B.O.D. The combined processes required 0.39 cu. ft. of air per gallon at an aerator detention of less than 3 hr. As might be expected, modified aeration produced a somewhat more concentrated sludge than did activated aeration. However, although using about 80 per cent of the quantity of air required by the combined processes, modified aeration discharged to the receiving stream twice as much pollution.

Inasmuch as the activated aeration process has demonstrated improved efficiencies at significant savings in power costs with respect to modified aeration, it has been adopted as a standard treatment procedure at the Wards Island plant. The plans for the new extension to the Bowery Bay plant include provisions for the use of activated aeration.

Effect of Aeration Time

The data given cover a rather narrow range of operating factors, since a major consideration was the necessity for the Wards Island plant to continue treating more than 200 m.g.d. of sewage. The activated aeration battery was required to use at least two aeration tanks to handle the flow of 55 m.g.d., thus setting a minimum aerator detention of 2.8 hr. In order to determine the effect of shorter contact time on process efficiency, samples were collected from the end of each of the four passes of one aeration tank. The samples were settled quiescently for 30 min. to simulate settling in the final tanks. The supernatants were composited for the day at each location and analyses were made for suspended solids and B.O.D. These results indicate what might be expected with aeration detentions of 0.7, 1.4, 2.1, and 2.8 hr. The averages for the six days of sampling are shown as nonsettleable suspended solids and B.O.D. *versus* aeration time in Figure 4. Also shown, for comparison, are the corresponding values for the final tank effluent. In general, with increasing time of aeration, there was a continuous lowering of the suspended solids and B.O.D. of the supernatant of settled aerator liquor, but at

a diminishing rate. The suspended solids at the end of the aerator did not agree with the trend and differed considerably from the final tank effluent values for the period. Evidently, settling aerator liquor in a beaker did not accurately simulate final tank performance with respect to suspended solids. On the other hand, the B.O.D. values were in closer agreement. The B.O.D. curve showed that up to 2.8 hr. of aeration, increasing the aerator detention resulted in improvement of the removal efficiency.

From Figure 4, it appeared that higher removals could be attained by increasing aeration detention to more than 2.8 hr. By placing a third aeration tank in service, the detention would be increased to more than 4 hr. However, this procedure was delayed until December, when lower sewage temperatures would permit the thickeners to handle the anticipated increase in load. Air requirements were increased to 0.3 cu. ft. per gallon by the necessity for maintaining solids in suspension in three aerators.

The December results showed that the use of three aerators produced a significant increase in process efficiency. The process effluent averaged 21 p.p.m. of suspended solids and 20 p.p.m. of B.O.D. for the month, representing removal efficiencies of 86 and 84 per cent, respectively. The thickened sludge averaged 3.0 per cent solids. The efficiency of the combined step aeration and activated aeration batteries was increased to 90 per cent removal of suspended solids and 89 per cent of B.O.D. at an over-all air ratio of 0.41 cu. ft. per gallon. Thus, under these conditions of operation, the combined process efficiency approached that of the activated sludge process. As opportunities present themselves, it is expected that various changes in operat-

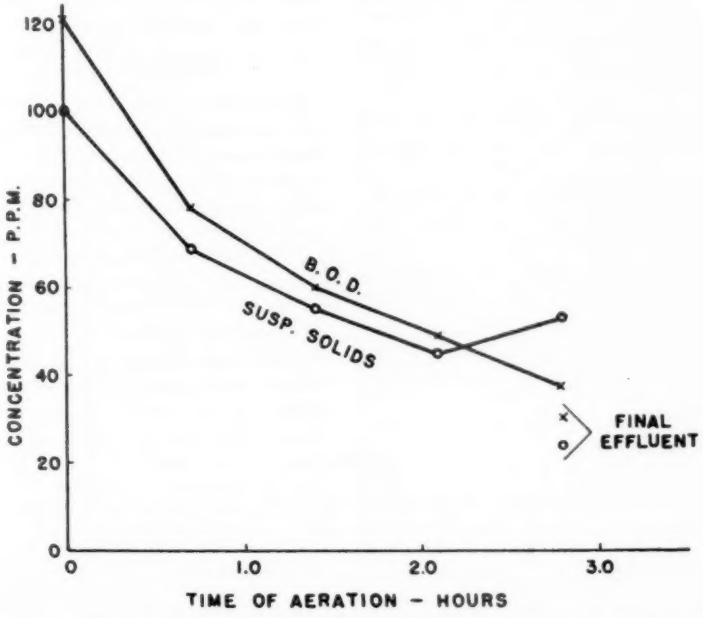

FIGURE 4.—Six-day average non-settleable suspended solids and B.O.D. *vs.* aeration time for activated aeration.

ing procedures will be investigated to determine if similar high efficiencies can be achieved using shorter aerator detentions.

Possible Applications

This new combination of activated aeration and activated sludge affords a considerable increase in flexibility to the activated sludge process. Variation in the operating conditions makes possible efficiencies between the limits from straight aeration to full activated sludge. The combined processes may thus be adapted to the needs of a particular plant or situation. For example, at a plant where satisfactory operation of the activated sludge process can no longer be maintained because of overloaded aerators, stability may be restored by using activated aeration to reduce the load on the activated sludge units.

Such an application of activated aeration would result in other benefits. The accompanying reduction in air requirements would significantly reduce power costs. The volume of excess sludge would be reduced, which would be of special significance where sludge digestion is employed. It may also be expected that gas production from the digesters would be increased, inasmuch as the solids removed by activated aeration have not undergone some four days of aerobic activated sludge digestion. These considerations indicate the desirability of plant-scale trials of the activated aeration process at other locations, especially where the full range of operation may be explored.

Summary

A new process, called activated aeration, which comprises the re-use of excess activated sludge solids, has been operated at the Wards Island plant for more than nine months. In this process, primary effluent was aerated for 2.8 hr. in the presence of the excess activated sludge from an adjacent unit. After final settling, the solids were wasted directly to thickening tanks, thus insuring process stability. Air requirements, averaging about 0.2 cu. ft. per gallon, were close to the minimum needed to keep solids in suspension in the aeration tanks and distribution channels. Process effluent, including that from the thickening tanks, averaged 31 p.p.m. of suspended solids and B.O.D. The combination of activated aeration and activated sludge accomplished a reduction of 86 and 85 per cent in the respective raw sewage suspended solids and B.O.D. These efficiencies were significantly increased when the activated aeration detention time was increased to 4.4 hr.

Acknowledgments

Thanks are extended to D. B. Keehan and the operating staff of the Wards Island sewage treatment plant for their cooperation in conducting this plant-scale investigation. The author wishes to express his gratitude to W. N. Torpey, Senior Civil Engineer, for his aid and advice in conducting these tests and in presenting the data, and to Commissioner Frederick H. Zurmuhlen, whose deep interest in improved techniques made the operational tests possible.

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BIOCHEMICAL DEGRADATION OF SYNTHETIC DETERGENTS *

I. Preliminary Studies

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The relatively recent appearance of synthetic organic detergents and their rapidly expanding use in the place of soaps has had an adverse effect on sewage treatment and on water purification. Numerous reports (1)(2)(3) tell of excessive frothing in the aeration tanks of activated sludge plants. It has been claimed that synthetic detergents seriously interfere with water treatment processes. Recent reports (4)(5) would indicate that as little as 1 to 2 p.p.m. of anionic surface-active agents can have a serious effect on chemical coagulation and on lime softening. Little is known at the present time regarding the effects syndets have on fresh-water gamefish. However, it has been reported (6)(7) that certain synthetic detergents may be toxic to fresh-water fish in concentrations not much greater than currently being encountered in some receiving waters. Serious questions have been raised concerning the ability of conventional sewage treatment processes to cope with these synthetic detergents.

This investigation was concerned with the biochemical degradation of the principal detergent types used in compounding the retail mixtures of commerce at the time of the study. Of immediate concern was the biochemical oxidation of these syndets, both under conditions representative of biological sewage treatment practice and under conditions which simulate the natural biological purification processes of receiving waters.

* Presented at 25th Annual Meeting, New England Sewage and Industrial Wastes Assn.; Boston, Mass.; April 22–23, 1954.

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Fundamental Considerations

The aerobic biological degradation of naturally occurring organic compounds has been the subject of much study. Although the aerobic metabolism of carbohydrates, fats, proteins, and related substances is not yet fully understood, sufficient knowledge does exist for the successful application of aerobic biological purification processes in sewage treatment and for a practical evaluation of the purification capacity of receiving streams for natural organic pollutants. The advent of synthetic detergents has witnessed the introduction of appreciable quantities of man-made organic compounds into sewage and some surface waters. Many of these synthetics bear little resemblence to the naturally occurring organic substances hither-to encountered. It is small wonder serious doubts have been raised regarding the susceptibility of many synthetic detergents to biological degradation.

Consideration of the rather unique physical chemical behavior of syndets—such as their lack of sensitivity to Ca^{++} and Mg^{++} ions and their ability to decrease surface energies—helps to explain how these substances could be troublesome. However, this does not fully explain why syndets have been a problem. There is one fundamental question which underlies all the other problems associated with synthetic detergents and that is their susceptibility to biological degradation. It should be recognized that if the biochemical behavior of syndets was similar to that of common soaps they would be of little concern. Obviously, if all synthetic detergents were readily assimilated by conventional biological sewage treat-

ment processes or by the natural biological purification agencies of receiving waters they would not persist for long and, consequently, would have little opportunity to make their presence felt.

Selection of Commercial Syndets for Study

Since the first introduction of synthetic detergents to the United States, more than 20 years ago, hundreds of synthetic surface active agents have been developed and patented. Today, there are available commercially many hundreds of surface-active agents, representing practically all classes of organic compounds. Current developments are aimed largely at producing specific agents to meet rigid specifications for specialized application and, also, at producing general purpose agents on a large scale and at a lower cost. The synthetic detergents for household and most industrial usage fall into the latter group. Significantly, only a relatively few compounds have been employed to date in appreciable quantities.

Synthetic detergents have been classified as anionic, cationic, or nonionic, according to the ionizing nature of the hydrophilic group of the detergent molecule. The anionic type currently represents approximately 85 per cent of the syndets encountered in sewage treatment practice (8). The nonionics represent approximately 10 per cent of the total syndet production and are reported as finding increased popularity (9). The balance of the syndets are represented chiefly by the cationics.

The cationic surface-active agents are not widely used for their washing ability, but are most generally employed for their bactericidal and bacteriostatic properties. A highly significant characteristic of the cationic agents is that they are precipitated by anionic types and thereby lose their identity as surface-active agents, as well as their bactericidal properties. Most of the cationics are undoubtedly removed as a component of the sludge in primary tanks and, consequently, would not be a factor in subsequent aerobic biological treatment or in receiving waters where secondary treatment is not practiced.

The annual production and sales data published by the United States Tariff Commission (8) have been used as a basis for the selection of those commercial synthetic detergent types which should be studied. These data have been summarized in Table I, where the major syndet classes and types and representative commercial products are shown, together with the annual poundage produced and the relative percentage which each category represents.

Experimental Procedure

The procedure employed in these studies was to follow the biochemical oxidation of commercial synthetic detergents by means of the Warburg apparatus and by the standard dilution B.O.D. technique (10). An acclimated activated sludge and domestic sewage were used as seed in the B.O.D. determinations.

The activated sludges used throughout the preliminary studies were developed from a domestic sewage seed and were maintained on a twice daily feeding of Weinberger's synthetic sewage (11). This synthetic sewage has a 5-day B.O.D. of approximately 210 p.p.m., a pH of 8.2, 6.2 p.p.m. soluble phosphorus, 13.7 p.p.m. urea nitrogen, and approximately 25.3 p.p.m. of total nitrogen. Aeration solids were maintained at 1,200 to 1,500 p.p.m. by wasting mixed liquor according to daily suspended solids determinations. The laboratory activated sludge apparatus used was the same as that described by Helmers *et al.* (12).

In preparing the activated sludges for Warburg and B.O.D. analyses a 48-to 60-hr. adaptation period was employed. Each commercial synthetic de-

TABLE I.—Relative Quantities of Major Synthetic Detergent Types

Surface-Active Agents, Class and Chemical Type	Annual Production							
	1949		1950		1951		1952	
	(10^6 lb.)	% of Total	(10^6 lb.)	% of Total	(10^6 lb.)	% of Total	(10^6 lb.)	% of Total
I. Anionic	381	88.5	591	87.5	612	88.5	636	86
A. Cyclic	206.9	48	350	52	429.5	62	446.5	60.5
1. Alkyl benzene and petroleum aromatic compounds, sulfonated[1]	186.7	43.4	324.7	48.3	400.4	51.9	391.5	52.9
Ultrawet DS, k								
Santomerse 3								
Naccanol NRSF								
Kreelon 8D, 8G								
2. Alkyl naphthene compounds, sulfonated	2.5	0.6	3.4	0.5	2.5	0.4	5.7	0.7
Naccasol A								
3. All other sulfated and sulfonated cyclic compounds[2]	17.5	4	21.8	3.2	26.5	3.7	48	6.4
B. Acyclic	173.8	40.5	241.3	35.6	182.6	26.3	189.5	25.6
1. Acids, sulfated and sulfonated	3.7	0.9	4.2	0.6	4.3	0.6	3.3	0.5
2. Alcohols, esters, and petroleum aliphatic compounds, sulfated and sulfonated	120.8	20.2	170.1	25.1	128.1	18.5	139.7	18.9
Lauryl sulfate, Dupanol C								
Ester of sodium isethionate, Igepon AP-78								
3. Nitrogen-containing, sulfated and sulfonated	8.6	2.0	13.0	1.9	5.6	0.8	4.1	0.5
Sulfonated amide								
Sodium-N-methyl-N-oleoyl taurate								
Igepon T-77								
4. Oils, fats, and waxes, sulfated and sulfonated[3]	40.7	9.4	54	8	43.9	6.4	42.4	5.7
II. Nonionic	30	7.0	51	7.5	47	6.8	63	8.5
A. Cyclic	15.0	3.5	30.5	4.5	25.9	3.8	26.9	3.6
1. Polyhydric alcohol ethers[4]								
Neutronyx 600								
Igepal CA-630								
B. Acyclic	14.6	3.4	20.4	3.0	20.8	3.0	36.3	4.9
1. Polyhydric alcohol esters, ethers, and amides[5]								
Armour Ethofats								
Armour Ethomids								
Polyglycol ethers								
Pluronics								
III. Cationics	18	4.5	33	4.9	30	4.7	41	5.5

[1] All members of this group have been typed as dedecyl benzene sulfonates and are generally referred to as such.

[2] Includes salts of lignosulfonic acid and many speciality products, such as sulfated and sulfonated phenyl esters, substituted biphenyls, and phenyl phenols. These substances are used principally in specific industrial applications.

[3] Consists principally of a large number of speciality products used in the textile industry; the majority are similar to the sulfated alcohols and acids.

[4] Principal type alkylphenoxy polyethoxy ethanol.

[5] Principal types, fatty acid esters and amides of polyethylene oxide.

tergent studied was added to the synthetic sewage during four consecutive feedings, using 50 p.p.m. of active agent. The sludge was not fed during the 24 hr. preceding its final use as the biological medium in Warburg and B.O.D. studies; this minimized the carry-over of unassimilated organic matter and provided a sludge which was generally in an endogenous state of respiration. Activated sludge concentrations of approximately 4,000 to 5,000 p.p.m. were used in the Warburg flasks. Seed material for the B.O.D. test was prepared by agitating 200 to 300 ml. of mixed liquor in a Waring blender for 30 sec. and then settling to separate coarse material from dispersed cells; 2 ml. of supernatant was used per liter of dilution water.

After a sludge had been used it was allowed to rest for 5 to 7 days, during which time it was fed synthetic sewage as before and reseeded daily with domestic sewage. Following this resting period the sludge was re-used as before with another synthetic detergent.

Generally, six activated sludge systems were kept in continual use with two under study, two undergoing acclimation, and the last two being rested. In certain cases where frothing was not controllable by adjusting the air supply, a commercial antifoaming agent (Dow Corning Antifoam A) was employed; usually 2 drops of this material would control foaming between feedings.

Experimental Results

For this investigation 36 different commercial synthetic detergents were obtained in the purest possible form from the principal manufacturers. Representative B.O.D. data and Warburg results obtained using 16 of these commercial detergents are briefly summarized in Table II and Figures 1 through 11. These data clearly illustrate two fundamental characteristics of all the detergents studied. First, all the major syndet types were susceptible to some degree of biochemical oxidation. Second, there was a considerable variation in susceptibility to biological degradation among members of the same chemical type, as well as among different detergent classes. These results are especially interesting in light of the conclusions of others (6)(13), which inferred that certain synthetic detergents, notably the alkyl aryl sulfonates, are biologically inert.

As shown in Table II, the use of acclimated activated sludges for seeding purposes in the B.O.D. determinations generally resulted in an increase in the values obtained, even though the activated sludge had been acclimated for only 48 to 60 hr. This increase in B.O.D. values was most pronounced with the more biologically resistant synthetic detergents, as might be expected, and it shows that these substances are not biologically inert.

The B.O.D. data in Table II are considered indicative of the potential behavior of these syndets in receiving waters. The Warburg data illustrate the general biochemical behavior of the principal detergent classes and types under aerobic conditions approaching the most rigorous oxidative environment generally attainable in biological sewage treatment practice. Certain types of syndets appear to be readily available as bacterial food and, therefore, are subject to rapid biological stabilization; included in this group are the alkyl sulfates (Figure 3), sulfonated fatty acid amides (Figure 5), sulfonated fatty acid esters (Figure 4), and certain fatty acid amides and esters of low molecular weight polyethylene glycols (Figures 7 and 9). The remaining synthetic detergents are at least partially available as bacterial food and, hence, are subject to a slight to moderate degree of biological degradation; included in this category are the alyklbenzene sulfonates (Figure 1), alkylnaphthalene sulfonate (Figure 2), the alkylphenoxy polyethylene oxide type (Figure 11), and derivatives of high molecular

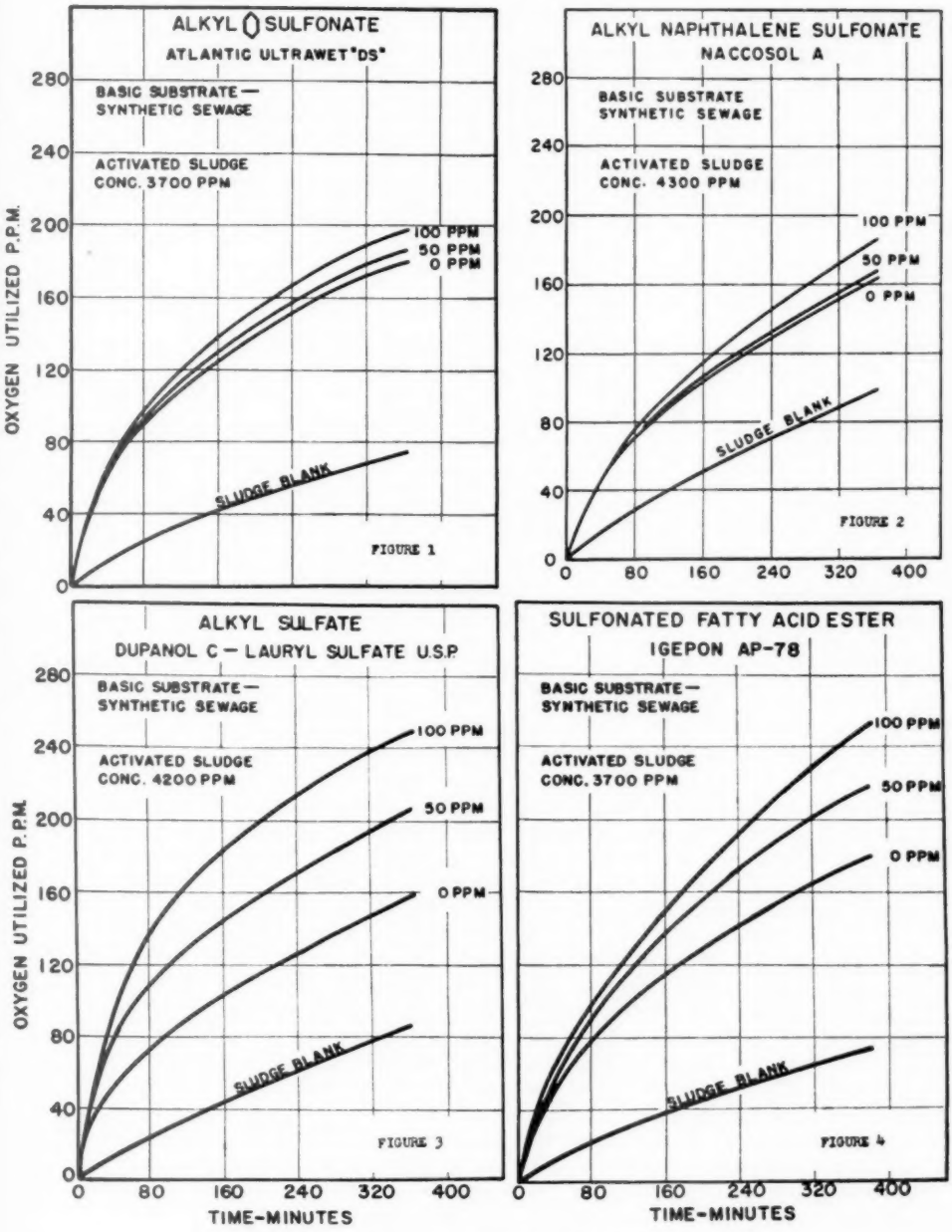
TABLE II.—Biochemical Oxygen Demand of Major Detergent Types

Surface-Active Agent, Class and Type	Theor. Oxygen Demand for Complete Oxidation (p.p.m.)	5-Day 20° C. B.O.D.[1]				Biochem. Oxid. by Warburg Technique[2]	
		Sewage Seed		Accl. Act. Sl. Seed			
		B.O.D. (p.p.m.)	% of Theor. O_2 Demand	B.O.D. (p.p.m.)	% of Theor. O_2 Demand	O_2 Util. by Syndet in 6 Hr. (p.p.m.)	% of Theor. O_2 Demand
I. Anionic							
A. Cyclic							
1. Alkyl benzene and petroleum aromatic sulfonates	2,370,000						
Atlantic Ultrawet DS		0	0	110,000	4.6	127,000	5.4
Monsanto Santomerse "3"		90,000	3.8	250,000	10.5	280,000	11.8
Wyandotte Kreelon 8D		150,000	6.3	506,000	21.4	200,000	8.5
Wyandotte Kreelon 8G		234,000	9.9	800,000	33.8	240,000	10.1
Allied Naccanol NRSE		0	0	419,000	17.6	258,000	10.9
2. Alkyl naphthalene sulfonate							
Naccasol A	2,300,000[3]	0	0	71,500	3.1	173,000	7.5
B. Acyclic							
1. Alcohols, esters and petroleum compounds, sulfated and sulfonated							
Dupanol C, Lauryl sulfate	2,030,000	1,250,000	61.5	1,330,000	65.5	920,000	45.2
Igepon AP-78, oleic ester of sodium isethionate	2,200,000	1,206,000	54.8	1,090,000	49.5	760,000	34.5
2. Nitrogen-containing, sulfated and sulfonated							
Igepon T-77, sulfonated amide	2,780,000	1,660,000	59.5	1,510,000	54.3	1,670,000	60.0

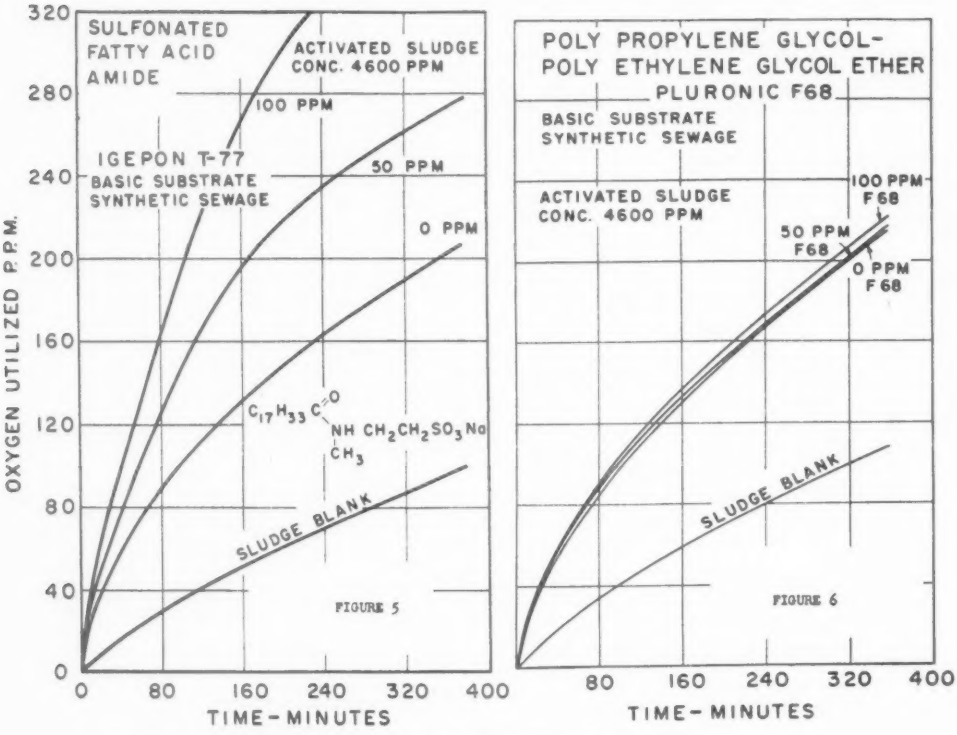
[1] By standard dilution technique.
[2] With acclimated activated sludge.
[3] Estimated.

TABLE II.—Biochemical Oxygen Demand of Major Detergent Types—*Continued*

Surface-Active Agent, Class and Type	Theor. Oxygen Demand for Complete Oxidation (p.p.m.)	5-Day 20° C. B.O.D.[1]				Biochem. Oxid. by Warburg Technique[2]	
		Sewage Seed		Accl. Act. Sl. Seed			
		B.O.D. (p.p.m.)	% of Theor. O_2 Demand	B.O.D. (p.p.m.)	% of Theor. O_2 Demand	O_2 Util. by Syndet in 6 Hr. (p.p.m.)	% of Theor. O_2 Demand
II. Nonionic							
A. Cyclic							
1. Polyhydric alcohol ethers							
Neutronyx 600	2,160,000[3]	0	0	116,000	5.4	254,000	11.8
Igepal CA-630	2,160,000[3]	132,000	6.1	124,000	5.7	440,000	20.4
B. Acyclic							
1. Polyhydric alcohol esters, ethers, and amides							
Polyethoxy ethanol fatty acid ester							
Ethofat C/15	2,200,000[3]	1,000,000	46.5	880,000	40	640,000	29.1
Ethofat C/60	1,880,000[3]	220,000	11.8	240,000	12.8	160,000	8.5
Polyethoxy ethanol fatty acid amide							
Ethomid HT/15	2,100,000[3]	996,000	47.5	880,000	42.0	412,000	19.5
Ethomid HT/60	1,950,000[3]	92,000	4.7	70,000	3.6	0	0
Polyglycol ethers Wyandotte Pluronic F68	1,840,000[3]	124,000	6	20,000	1.1	67,000	3.6



FIGURES 1-4.—Oxygen utilized in Warburg apparatus.



FIGURES 5-6.—Oxygen utilized in Warburg apparatus.

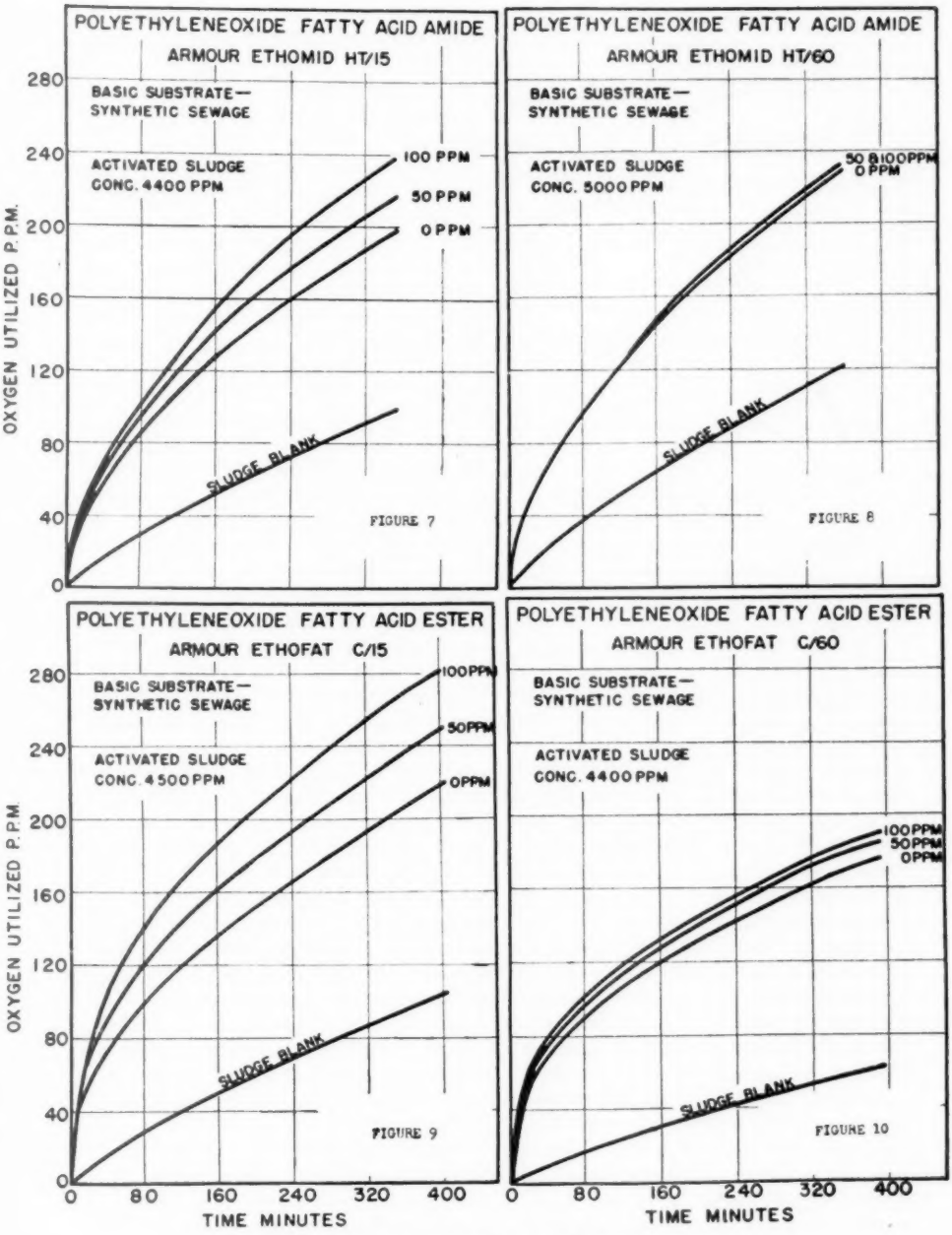
weight polyethylene glycols such as the amides (Figure 8), the esters (Figure 10), and the ethers (Figure 6).

These results indicate that classification of synthetic detergents as anionic or nonionic substances has little, if any, biochemical significance insofar as biological sewage treatment and biological purification of receiving waters are concerned. Examination of the data in Table II indicates that the alkyl aryl sulfonates behaved in one of two ways; either they were only sparingly assimilated or they were assimilated at a comparatively rapid rate. Generically, there is no basis for differentiating the alkylbenzene sulfonates of commerce and yet biochemically, so to speak, a marked difference does exist.

At no time throughout these studies was there any noticeable deterioration of the activated sludges due to the addition or presence of a synthetic detergent. The only unusual occurrence noted was a tendency of as much as 30 to 40 per cent of the aeration solids to rise to the surface immediately after aeration was halted. This phenomenon was of a random nature; its occurrence was neither related to the type of syndet present nor was it consistent. The floating solids tended to settle out as large loose floc particles after approximately 30 min.; gentle agitation helped to hasten their subsidence. Countless small bubbles, just visible to the naked eye, were observed in the floating sludge mass.

Discussion

A continued increase in the production and use of certain synthetic detergent types can be expected to ac-



FIGURES 7–10.—Oxygen utilized in Warburg apparatus.

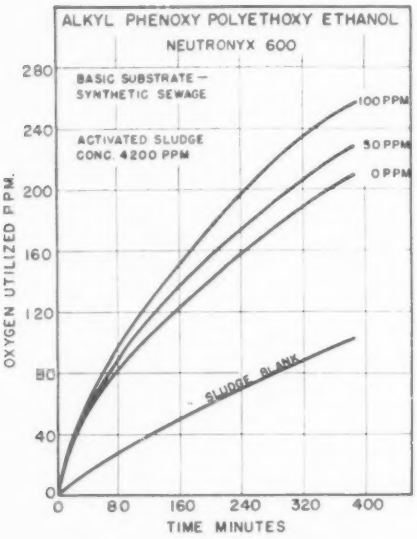


FIGURE 11.—Oxygen utilized in Warburg apparatus.

centuate many of the problems currently resulting from the presence of some synthetic organic surface-active agents in sewage and in receiving waters. The situation may become extremely serious in some locations, particularly if there is a continued trend toward a greater use of the synthetic detergent types which are most resistant to biological degradation. With such materials, adequate dilution is the only sure way of dissipating their effects in receiving waters.

Although the physical chemical properties of surface-active agents have a marked bearing on the effects caused by these substances, it is their biochemical behavior which determines whether or not a given syndet will be a problem. Most of the syndet-induced problems have arisen because of a fundamental difference in the physical chemical behavior of common soaps and synthetic detergents. Common soaps, unlike synthetic detergents, are readily precipitated or removed as scum in settling tanks or in receiving waters by naturally occurring calcium and magnesium ions. Consequently, most synthetic detergents, unlike common soaps, pass right through primary tanks and are still free to act as surface-active agents and to travel great distances in receiving streams, as shown in Figure 12.

Some syndets in concentrations as low as 5 p.p.m. are reported capable of forming very stable emulsions in ordinary domestic sewage (14). Because of the physical chemical behavior of synthetic detergents, several workers have predicted increased loadings on secondary treatment processes or on receiving waters where secondary facilities are not provided (14)(15)(16). Figures 12 and 13 illustrate certain fundamental differences in the physical chemical behavior of synthetic detergents and common soaps in sewage and in receiving streams.

The real burden of removing synthetic detergents from sewage has fallen on the accelerated biological purification processes of sewage treatment and on the natural biological purification processes of receiving waters. Certain synthetic detergents, such as the alkyl sulfate and the anionic fatty esters and amides, are readily assimilated by the mixed biological cultures indigenous to domestic sewage and, consequently, are not likely to be trouble makers. Other detergents, such as the alkylbenzene sulfonates and the alkylphenoxy polygycols, are only sparingly or very slowly assimilated by the mixed microbiological cultures of practice and are the source of most of the problems associated with synthetic detergents. Current commercial trends appear to be toward ever-increasing use of the latter group of syndets at the expense of the readily assimilated types (8)(9).

There is an immediate and real need for fundamental knowledge of the biochemical behavior of the principle synthetic detergent types. Some studies have been made both in the U. S. and abroad with a limited number of commercial synthetic detergents and with certain retail products. Plant-scale

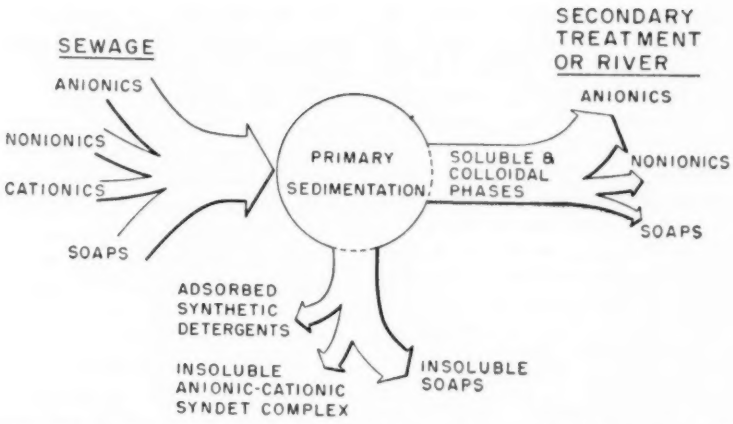


FIGURE 12.—Physical chemical behavior of soaps and synthetic detergents during primary treatment.

studies with commercial syndets can be of real significance in showing the effects that different surface-active agents have on sewage treatment and in indicating the efficacy of various treatment processes in removing these substances from sewage. Unfortunately, the nature and composition of most syndets studied—and quite often the experimental conditions—have not been adequately defined. Studies using retail packaged products have been of even less value unless the composition of the product at the time of study was well defined, a condition seldom realized, as the composition of a trade name product is generally being constantly varied and also may differ considerably from region to region. The results of this research demonstrate the need of a more basic approach to the study of the biochemical behavior of synthetic detergents.

Summary and Conclusions

A systematic survey of the major synthetic detergents of commerce has been made. The biochemical behavior of these syndets was studied under conditions representative of biological sewage treatment practice and under conditions which simulate the natural biological purification processes of receiving waters. The results of these preliminary studies show the following:

1. All the principal anionic and nonionic synthetic detergent types are susceptible to some degree of biological degradation.

2. There is a considerable variation in susceptibility to biological degradation, both among members of the same chemical type and among different detergent classes.

3. The observed resistance of syndets to biochemical oxidation is an extrinsic

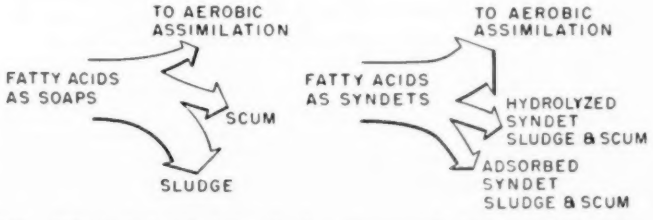


FIGURE 13.—Effect of chemical constitution on removal of fatty acids in primary tanks.

property of the biological medium. A relatively brief adaptation period of 48 to 60 hr. generally resulted in an increase in the extent to which the more resistant synthetic detergents were oxidized.

4. Certain synthetic detergent types are readily available as bacterial food and, therefore, are subject to rapid biological stabilization; included in this group are the alkyl sulfates, sulfonated fatty acid amides and esters, and certain derivatives of low molecular weight polyethylene glycols.

5. The alkylaryl sulfonates, alkylphenoxy polyglycols, and derivatives of high molecular weight polyethylene glycols are biochemically stabilized at a relatively slow rate.

6. Classification of synthetic detergents as anionic or nonionic substances has little, if any, biochemical significance insofar as biological sewage treatment and biological purification of receiving waters are concerned.

7. The biochemical degradation of synthetic detergents is a function of their chemical constitution and can be strongly influenced by seemingly small changes in the nature of certain molecular components.

Acknowledgments

The investigation described herein was supported by a grant from the National Institutes of Health, U. S. Public Health Service.

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EFFECT OF SYNTHETIC DETERGENTS ON THE SETTLING OF SUSPENDED SOLIDS

By P. N. Degens, Jr., H. van der Zee, and J. D. Kommer

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Sewage plant managers often express the fear that settling of suspended solids in primary settling tanks is adversely affected by synthetic detergents on account of their dispersing properties even in hard water. Fatty acid soaps, on the other hand, lose their dispersing properties in hard water.

Given such an adverse effect the result would be that:

1. The quantity of precipitated sludge is smaller, so that less methane is formed.
2. The sludge may be much more bulky, so that per cubic meter of sludge less organic matter is processed in the methane fermentation tanks.
3. The clarified liquid contains a larger quantity of nonsettled organic particles, so that the biological purification plant is more heavily loaded.

The experiments on the influence of syndets on the primary settling of raw sewage described in literature are rather contradictory. Goldthorpe (3), Lumb (6), and Rudolfs (10), for instance, conclude from their laboratory experiments with Imhoff cones that syndets at a concentration of 100 p.p.m. (as sold) have an adverse effect on the sedimentation of the settleable solids. Sperry (13) also comes to this conclusion by comparing his statistical operation data of the years 1938–50. In drawing this conclusion, however, no allowance has been made for a possible decrease in the quantity of primary sludge due to a decrease in fatty acid soap consumption during the last few years.

Other investigators—for example, Gaillard (1), Hurley (4), Merrill (8), Oldham (9), and Seiver (11)—conclude from their laboratory experiments that no influence of anionic (alkyl sulfates, Teepol; as well as alkylaryl sulfonates, Dreft) or nonionic (Lissapol N) syndets (up to 100 p.p.m. as sold) on the primary settling is noticeable. This could even be confirmed by Hurley (4) in full-scale experiments with Teepol.

To obtain more data, the authors of this paper have also made sedimentation experiments in Imhoff cones with synthetic sewage to which different quantities of detergents had been added. The fatty acid soap/syndets ratio was thus kept completely under control.

The standard procedure followed for the preparation of the synthetic sewage was such that the precipitate of the calcium fatty acid soap was finely dispersed and could not settle. This was done because there also are indications that in practice only a very small quantity of the calcium fatty acid soaps is carried out in the primary sludge.

Gehm (2), for instance, found that laundry waste, which is discharged in large quantities on Mondays and Tuesdays, caused the increase in strength to be proportionally much greater in the settled sewage than in the raw sewage. According to him this might be attributable to the fact that the suspended solids in the laundry wastes are finely dispersed and settle less readily than the suspended matter in sewage.

Lumb (7), on the other hand, says that where soap is used substantially in the household the whole of it finds its way naturally into the sludge via

the hardness of the water, and is then available as a producer of methane gas.

The last concept fits with theory, for the water and soap consumption per capita, as well as the hardness of the water, is generally such that all the fatty acid soap is present in the sewage as the calcium salt and only a small quantity of this calcium salt will be dissolved molecularly.

On the basis of solubility of calcium stearate (46 mg. per liter) (see 12) in water with 0.05 per cent sodium chloride it can be calculated that a water hardness of more than 50 p.p.m. only slightly influences the quantity of calcium stearate which remains dissolved, for from Figure 1 it is evident that when the hardness of the water is raised from 50 p.p.m. to 300 p.p.m. calcium oxide the solubility of the calcium stearate only decreases from 15 to 6 mg. per liter.

In general, therefore, it may be expected that the bulk of the calcium fatty acid soap in sewage has precipitated, but it will depend on the nature of this precipitate whether it will settle and be discharged with the primary sludge, or will be carried along with the settled sewage to the biological purification section.

It has been found that the nature of a calcium stearate precipitate depends largely on the conditions under which the calcium salt is formed. When, as is usual in the washing process, the suds are made in hot water, a finely dispersed, colloidal precipitate is formed which does not settle. If the suds are made in cold water, however, only a flaky, settleable precipitate of the calcium soap is formed when the water has a high degree of hardness (Table I).

The results (Table II) obtained by determining the fatty acid content (5) in an Imhoff cone before and after 1-hr. settling in some samples of raw sewage taken at various times from the Amsterdam-West sewage works show that, on an average 80 per cent of the fatty acids present in the Amsterdam raw sewage in the form of calcium soaps does not settle under the given experimental conditions.

The foregoing facts point in the same direction as indicated by Gehm (2); that is, a considerable part of the

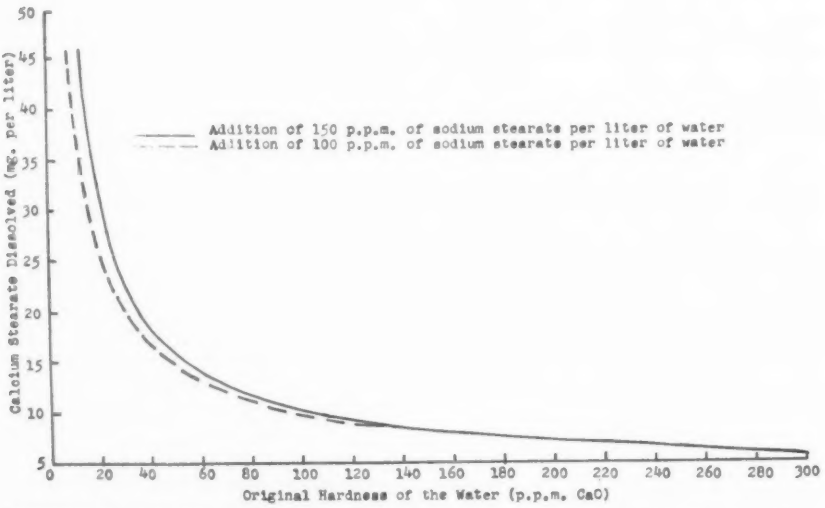

FIGURE 1.—Solubility of calcium stearate in water (+ 0.05 per cent NaCl) of different degrees of hardness (after addition of 100 and 150 p.p.m. of sodium stearate).

TABLE I.—Nature of Calcium Stearate Precipitate Formed under Various Conditions

Procedure	Hardness of $CaCl_2$ Solution (p.p.m. CaO)		
	25	100	700
150 mg. sodium stearate added to 1 l. of hot, diluted $CaCl_2$ solution	Turbid, no sludge after standing 1 hr.	Same	Same
150 mg. sodium stearate added to 1 l. of cold, diluted $CaCl_2$ solution	Turbid, no sludge after standing 1 hr.	15 ml. of sludge after 1 hr.; about 30% of the calcium soap had settled according to B.O.D. test	60 ml. of sludge after 1 hr.; about 80% of the calcium soap had settled according to B.O.D. test

calcium fatty acid soaps will be carried along with the settled sewage and will not settle as sludge.

In the settling experiments in the laboratory, therefore, such conditions of calcium stearate formation have been chosen that a colloidal, dispersed precipitate is formed which does not settle after standing for 1 hr. in an Imhoff cone. In this way reproducible and comparable results are obtained concerning the effect of syndets on the sedimentation of the faeces, which form the bulk of the primary sludge.

Preparation of Synthetic Sewage

The synthetic sewage consisted of a mixture of faeces and urine in tap water to which carbon black, starch, and peptone had been added. The faeces and urine were diluted with tap water (hardness 140 p.p.m. calcium oxide) to such a degree that the mixture, after having been put aside for 1 hr. in an Imhoff cone, had a sludge volume of about 30 ml. (solution A). This concentration of sludge, which was much higher than that found in practice, was chosen so as to have a sufficient quantity of sludge available for the various analyses. To a beaker glass with 100 ml. of distilled water were added 150 mg. of peptone, 150 mg. of soluble starch, 15 mg. of norit, and the quantity of detergent necessary ultimately to obtain the desired concentration in 1.5 l. of water. This mixture was brought to a boil while stirring and then poured into 400 ml. of boiling tap water. The 500 ml. of dirty suds (solution B) thus obtained was cooled and mixed with 1 l. of the faeces water (solution A).

Procedure of Settling Experiments

Synthetic sewage (solution C) in the amount of 1 l. was poured into an Imhoff cone and after 1 hr. the sludge volume was read off. The effluent was then carefully passed into a flask to constitute the effluent sample. The sludge with part of the effluent was quantitatively rinsed into a 50-ml. measuring cylinder. After settling, the supernatant liquid was sucked off until the remaining quantity in the 50-ml. measuring cylinder was equal to the sludge volume in the Imhoff cone. This remaining quantity was kept in

TABLE II.—Fatty Acid Content in Raw and Settled Sewage

Fatty Acid in Raw Sewage (mg./l.)[1]	Fatty Acid in Settled Sewage (mg./l.)[1]	[1]Ratio of Fatty Acid, Raw to Settled (%)
42	38	90
75	54	72
85	70	82
93	71	76
105	87	83
131	98	75
120	100	84
71	68	96
—	—	82[2]

[1] Calculated as sodium stearate.
[2] Average.

TABLE III.—Sludge Analyses for Sedimentation Experiments with Syndets[1]

Detergent Added (p.p.m.)		Sludge Volume (ml.)						Dry Solids (mg.)						Carbon (mg.)					
Sodium Stearate	Syndet[2]	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
(*a*) With Teepol Addition																			
0	0	23	25	31	29	22	27	230	345	388	406	348	378	88	153	180	183	156	176
150	0	24	25	31	29	20	27	228	330	412	426	306	375	106	143	171	200	130	162
100	25	27	23	30	30	20	27	248	311	366	402	332	362	111	122	168	192	148	176
50	50	20	25	28	30	20	27	214	328	386	408	326	365	90	180	182	201	136	151
0	75	19	26	32	30	19	29	219	348	413	354	317	339	99	216	195	183	141	154
(*b*) With Lissapol N Addition																			
0	0	22	26	22	25	22	—	288	356	392	520	343	—	132	185	176	263	150	—
150	0	23	26	21	24	23	—	301	359	302	367	311	—	129	172	141	178	140	—
100	25	23	26	21	27	20	—	313	367	321	486	300	—	140	166	147	216	148	—
50	50	21	27	22	23	21	—	298	397	321	414	363	—	147	176	143	193	210	—
0	75	21	26	23	27	23	—	292	387	366	435	338	—	124	177	159	184	166	—

[1] In all experiments 1 l. of synthetic sewage with additions (solution C) was used as base material.
[2] Active matter.

TABLE IV.—Effluent Analyses for Sedimentation Experiments with Syndets[1]

Detergent Added (p.p.m.)		Dry Solids (mg.)						Carbon (mg.)						B.O.D. (p.p.m.)					
Sodium Stearate	Syndet[2]	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
(a) With Teepol Addition																			
0	0	1,055	1,180	1,269	1,272	1,223	1,265	405	502	521	512	540	485	490	732	727	685	680	670
150	0	1,181	1,297	1,434	1,427	1,460	1,469	512	648	612	600	679	605	710	930	988	905	915	935
100	25	1,138	1,290	1,407	1,358	1,431	1,430	457	625	589	539	632	591	685	828	910	863	795	850
50	50	1,184	1,245	1,397	1,384	1,408	1,437	479	545	556	558	624	586	678	805	840	838	700	800
0	75	1,213	1,254	1,391	1,365	1,400	1,337	411	486	576	487	596	546	555	675	745	785	735	745
(b) With Lissapol N Addition																			
0	0	1,174	1,237	1,125	1,199	1,203	—	480	516	511	511	488	—	625	775	835	805	750	—
150	0	1,309	1,422	1,302	1,484	1,387	—	563	649	601	643	552	—	880	1,080	1,080	1,085	1,055	—
100	25	1,270	1,334	1,263	1,352	1,333	—	526	617	575	607	549	—	810	995	1,055	1,005	955	—
50	50	1,243	1,314	1,281	1,368	1,273	—	528	565	572	610	488	—	745	885	985	910	825	—
0	75	1,243	1,295	1,251	1,352	1,290	—	526	577	556	583	513	—	645	760	875	855	765	—

[1] In all experiments 1 l. of synthetic sewage with additions (solution C) was used as base material.
[2] Active matter.

a flask and represented the sludge sample.

The dry solids content and the carbon content of the various sludge and effluent samples were determined (wet oxidation method), as well as the B.O.D. value of the effluent samples.

To obtain comparable results each time, a series of five sedimentation tests was started simultaneously with the same faeces solution A; specifically, a blank (solution A + solution B without syndets and soap), and four experiments with solution A + solution B in which the soap and syndets concentrates were varied. The concentrations of fatty acid soap in the synthetic sewage (solution A + solution B = solution C) varied from 0 to 150 p.p.m., those of the syndets from 75 to 0 p.p.m. calculated on active matter.

The effect of two types of syndets on the settling of the suspended solids was determined; namely, of an anionic detergent of the sodium alkyl sulfate type (Teepol) and of a nonionic polyglycol ether of an alkylated phenol (Lissapol N).

In view of the spread in the results, each test series was carried out at least in five-fold and by statistical treatment of the results the actual significance of the differences obtained with the various proportions of fatty acid soap and syndets was determined, the quantity of dry matter (carbon compounds) added to the sodium stearate and the syndets being taken into account.

Results of Settling Experiments

Details of the six test series with Teepol and sodium stearate are given in Tables IIIa and IVa, those of the experiments with Lissapol N and sodium stearate in Tables IIIb and IVb.

Sludge Analysis

Average sludge analyses of the various test series of Table III are summarized in Table V.

According to a statistical analysis of the results, the differences found between the various test series and the blanks are not significant, so that the following conclusions can be drawn:

1. Under the given test conditions the sludge volume read off after 1 hr. in an Imhoff cone is the same for Teepol and Lissapol N at varying quantities of fatty acid soap and syndets.
2. The concentration of dry solids in the sludge remains the same at the various concentrations and ratios of the two detergents examined. From this it may be concluded that the sludge has not become more bulky (bulky sludge) with respect to the blank in the presence of these syndets in the sewage.
3. The carbon content of the sludge is constant, so that in all cases a similar quantity of organic matter of identical nature has settled. This means that the methane production from the sludge of the various test series can be expected to be the same.

TABLE V.—Average Results of Sludge Analyses (from Table III)

Detergent Added (p.p.m.)		With Teepol Addition			With Lissapol N Addition		
Sodium Stearate	Syndet[1]	Sludge Vol. (ml.)	Dry Solids (mg.)	Carbon (mg.)	Sludge Vol. (ml.)	Dry Solids (mg.)	Carbon (mg.)
0	0	26	349	156	23	382	181
150	0	26	346	152	23	328	152
100	25	26	337	153	23	357	163
50	50	25	338	157	23	359	174
0	75	26	332	165	23	364	162

[1] Active matter.

Effluent Analysis

The foregoing conclusions also can be drawn from the analytical results of the effluent (see Table VI), specifically:

1. The quantity of dry solids in the effluent remains the same for the various detergent concentrations when the quantity of dry solids added is taken into account, for the detergents added have mainly dissolved in the effluent or have remained suspended.

2. From the B.O.D. values of the effluent and the quantity of carbon it can also be concluded that with respect to the blanks the quantity of organic matter remaining behind in the effluent as a result of the influence of the detergents added is not larger than is to be expected on the basis of these additions.

Conclusion

Under the conditions of the experiments no adverse influence on the sedimentation of raw synthetic sewage is observed as a result of the presence of Teepol (a secondary alkyl sulfate) or Lissapol N (a polyglycol ether of an alkylated phenol) in concentrations of 25 to 75 p.p.m. active matter.

The quantities and the volumes of the settled organic mass are in all cases equal to those of the blank. No indications have therefore been obtained that less (and/or more bulky) sludge has settled under the influence of these types of syndets, with resulting heavier loading of the biological treatment units.

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TABLE VI.—Average Results of Effluent Analyses (from Table IV)

Detergent Added (p.p.m.)		With Teepol Addition[1]								With Lissapol N Addition							
		Dry Solids (mg.)			Carbon (mg.)			B.O.D. (p.p.m.)		Dry Solids (mg.)			Carbon (mg.)			B.O.D. (p.p.m.)	
Sodium Stearate	Syndets[2]	In Eff.	Added as Detergent	Corr. for Detergent	In Eff.	Added as Detergent	Corr. for Detergent	In Eff.	Added as Detergent	Corr. for Detergent	In Eff.	Added as Detergent	Corr. for Detergent	In Eff.	Added as Detergent	Corr. for Detergent	In Eff.	Added as Detergent	Corr. for Detergent
0	0	1,211	0	1,211	494	0	494	664	0	664	1,188	0	1,188	501	0	501	758	0	758
150	0	1,378	150	1,228	609	106	503	897	250	647	1,381	150	1,231	602	106	496	1,036	250	786
100	25	1,342	133	1,209	572	84	488	822	190	632	1,300	125	1,175	575	86	489	964	167	797
50	50	1,342	117	1,225	558	61	497	777	150	627	1,296	100	1,196	553	68	485	870	84	786
0	75	1,327	100	1,227	517	39	478	707	80	627	1,286	75	1,209	551	49	502	780	0	780

[1] The Teepol used contains 6 to 7 per cent Na_2SO_4 in addition to 21.7 per cent active matter.
[2] Active matter.

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SEWAGE FACILITIES IN CIVIL DEFENSE EMERGENCIES

A bulletin on "Sewage Works Facilities in Civil Defense Emergencies," has been issued by the Federal Civil Defense Administration as a guide for all concerned with maintenance and operation of this vital utility.

Operational responsibility for restoration of sewage service in emergencies is outlined, together with suggestions as to mutual aid, mobile support, and liaison with other utilities and services.

The bulletin also covers the effects of atomic, thermonuclear, and conventional weapons on sewage works facilities, stresses the necessity of pre-attack planning of emergency locations and procedures, and points out that the emergency organization and training must be carried on long before an attack becomes probable.

Suggested emergency sanitation measures include use of excreta bags, manholes, latrines, and chemical toilets.

Under post-attack operation, the bulletin gives a check list of general procedures to be followed in assessing the situation and the repairs needed, then notes some of the repair items that may be required on short notice.

The pamphlet is available as "Civil Defense Technical Bulletin TB–13–10" (June, 1954) from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at $0.05 per copy.

STANDARDS FOR SANITARY SEWERS AND PRESENT COMMUNITY NEEDS*

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Difficulty with sewage collection and disposal is one of the most troublesome symptoms of "suburbanitis," a malady of metropolitan districts which is causing noticeable distress in many parts of the country. The rapid development of new residential communities in townships adjacent to the larger cities results in requirements for drainage and other services which severely strain local finances. At the same time building sites provided with public water and sewerage are in great demand, and increasingly hard to find.

At a recent conference on land planning in Buffalo, it was stated that the present Town Law of New York is in need of considerable modification to permit the towns to cope with the demands for services which are being placed upon them by rapid growth. Provision of trunk sewers is particularly difficult under present law.

It is axiomatic that effective community planning is the best protection against unsound land development, but in many towns planning boards have little enforcement power and act chiefly in an advisory capacity.

In the absence of any well-formulated drainage plan, and because of the section in the State Public Health Law requiring Health Department approval of water and sewage arrangements in subdivisions, public health engineers often find it necessary to accept sewerage arrangements which do not seem in accord with the best long-term community development. In Erie County, where the soil generally has low absorptive capacity, it is felt that public sewers usually offer the preferred solution and that they will prove more economical in the long run than private disposal systems. This is not equally true in rural areas where houses are scattered and are constructed on large lots.

In many growing communities local officials must sooner or later seek an answer to such questions as the following:

What is the extent of the metropolitan area which should be served with public sewers as its develops?

What, if anything, should be done to discourage within the foregoing area any development which is not to be served by public sewerage?

There are many difficulties which sometimes prevent construction of sanitary sewers in new areas, and where satisfactory types of private sewage disposal systems are proposed it becomes necessary for the Health Department to approve them. It is realized, of course, that construction of a few private systems in a neighborhood may interfere with future financing of public sewers, because owners of houses equipped with private systems are reluctant to support construction of a public system.

It is also necessary to recognize, however, that many of the sanitary sewers being built are failing to perform their function satisfactorily.

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

Operating Difficulties

In every township within Erie County where sanitary sewers have been constructed, severe problems have arisen due to flooding of basements and surcharging of sewers with ground and surface water. The intense and often bitter reaction of the public to incidents of this type can only be fully appreciated by the public official who must explain the occurrences to those affected. Such conditions also result in overloading of treatment units and impairment of their pollution abatement function. Actually, these sanitary lines are being used as combined sewers. Moreover, where storm drains are built they often receive sanitary drainage. In one sanitary sewer district the sewage flow increases tenfold at the treatment works after storms, although there are overflows from the system to the stream at other points. In another district the recently built sanitary sewers flowed full after rain, even before all house connections were made. Connection of these sewers to an adjacent village system increased the overload on the village sewers, necessitating installation of an overflow to a surface ditch. There was full-time inspection provided on these sewers. A further case may be cited where the finished system passed leakage tests under the supervision of the designing engineer. Flow at this treatment plant increases fourfold within one hour after rainfall begins. Very little storm flow reaches these lines from roofs or streets.

TABLE I.—Results of 24-Hr. Composite Tests of Raw Sewage[1]

Plant	5-Day B.O.D. (p.p.m.)	Susp. Sol. (p.p.m.)	Date
A	84	248	5/1
B	72	61	4/30
C	74	45	4/29
D	92	120	4/28

[1] No rain for one week prior to samples.

In some areas surcharged sanitary laterals are being equipped with overflows to relief sewers. This practice requires construction of the relief lines at excessive depths and is therefore uneconomical. It also is a violation of present state requirements.

Table I shows the results of 24-hr. composite tests of raw sewage at several treatment plants made by the Erie County laboratory.

All of these plants serve residential communities and no industrial cooling or process water reaches the sewers. It is believed that the diluted character of the flow is due to ground water, and that admission of ground water to the sewers plays an important part in the difficulties previously outlined.

Many other instances could be cited to show that sanitary sewers are not performing in the manner intended by the designer. Their utility is thereby greatly impaired. Correction of the existing defects and prevention of additional ones will require increased attention on the part of consulting engineers and the understanding and cooperation of contractors, home builders, municipal officials, and regulatory agencies. The issues must also be made clear to the public using the sewers.

If it can be shown that sewers to handle ground or surface water are needed, provision should be made for them in the early stages of community development. If separate sewers are not provided, consideration should be given to providing the necessary extra capacity in the single sewer which is built.

Proper enforcement of permissible sewer uses is the responsibility of the owner. The adoption of an adequate local ordinance such as that recommended by the Federation of Sewage Works Associations (1) is very helpful in this regard. The introduction to this ordinance states: "There is no question but that many problems of sewage treatment can be eliminated or

partially solved by proper regulation of the sewage collection system. Without such control a sewer system can not render satisfactory service and becomes a hazard to the public safety and entails a substantial waste of funds used for corrective construction."

The financing of sewers for a growing area is often the controlling factor in view of present high construction costs and local debt limitations. The collecting system cost customarily exceeds that of treatment and may account for more than 90 per cent of the cost of sewerage. Any possible method for reducing the cost of the sewers themselves, therefore, deserves very close attention.

Ground-Water Considerations

In a new area, consideration must be given to drainage of ground water and surface runoff, as well as to sanitary sewage. New York State is using the standards of the Upper Mississippi and Great Lakes Boards of Public Health Engineers, which state that only separate sewers will be considered unless special conditions exist. The permit is issued on the condition that only sanitary flow and no ground or surface waters be admitted. The standards appear to assume that storm-water sewers will eventually be provided, but little is done to require such construction until conditions become sufficiently unacceptable to create a public demand. Most towns are strained to the utmost to construct sanitary lines, without even considering storm sewers, which cost an equal amount or more. At the same time, new homes have experienced trouble with ground water in so many instances that the FHA and VA require that footing drains be provided on those properties where they guarantee loans. These agencies specify such drains be connected to a sewer, which they assume was designed to receive it. In the absence of storm or combined sewers, many builders connect foundation drainage to a sanitary line.

Footing drain tiles are now usually placed inside foundation walls and surrounded by gravel, crushed stone or cinders. Sometimes weep holes are placed through cellar wall footings to relieve pressure on basement walls in the event of flooding. Ground water outside the foundation or from roof leaders discharging near the house may, therefore, reach the footing drains, which are commonly connected to the cellar drain. This is usually followed by a trap and perhaps a backflow prevention device before the drains are connected to the house sewer. After a rain, sanitary sewers become surcharged, frequently to an extent that they back up into house sewers and flood cellars. When the house sewer becomes inoperative the discharge from footing drains adds to the liquid in the cellar.

If a backup prevention device between the floor drain and house sewer is installed and maintained properly, sewage will not reach the cellar; but at the same time footing drainage cannot escape and will overflow into the cellar. Cellars, therefore, may contain storm water, or sewage, or a mixture of the two, and may become holding tanks until excessive water can escape through the sanitary sewer.

Some home owners attempt to control these conditions by installing standpipes in the cellar drain extending up to about the level of the laundry tray overflow. If the junction between the floor and wall is waterproof this will be successful in moderate storms unless the floor cracks or fails under the pressure created.

Surcharging of sanitary sewers may result from one or more of the following:

1. Footing drainage.
2. Roof drainage.
3. Leaking joints in sewers, defective house connection, cracked pipe, etc.

4. Leaking manhole covers or abuse of manholes to drain surface water.

5. Discharge of street receivers to sanitary sewers.

In many cases where trouble has been experienced, roof drainage is not involved. It should never be permitted in a sanitary system. It is believed that the increase in sanitary flow after storms is too rapid to be due entirely to infiltration in the sewers, as the street sewers are usually surrounded by clay and covered with pavement. The worst abuse is where street receivers discharge to sanitary sewers. This results in discharge of surface runoff through sewers into basements.

The amount of water reaching footing drains depends on the care used in construction and on local soil and drainage conditions. Some contractors backfill around the foundation with rubble and loose soil, inviting excessive seepage of surface water, and also neglect to slope the ground away from structures. Because of many variations in construction practices and soil character it is impractical to predict flow in footing drains and it is held by some to be insignificant after the first year or two. However, various observations in Erie County indicate that two 4-in. open tile drains beneath cellars may flow one-half full in the first year and about ¼ in. deep after five years. In the first case, footing drains from a single house could discharge at a rate of 65,000 g.p.d. to the sewers. Such a rate has actually been observed. In the latter case, the flow might approximate a 3,000-g.p.d. rate. Current state standards for sanitary sewers call for a capacity of 400 g.p.d. in laterals flowing full, or an allowance of about 1,400 g.p.d. per house. The capacity of an 8-in. lateral at minimum grade equals 450,000 g.p.d. At 1,400 gal. per house such a sewer can handle about 300 houses. On the other hand, footing drains from 6 or 7 houses can exhaust its capacity at the high rates described.

It is evident that surcharging of an 8-in. lateral cannot be prevented by providing a relief overflow at its lower end if its capacity is exceeded upstream of the point of overflow, although this is sometimes proposed as a remedy. Full correction of flooding will often require construction of an entirely new sewer.

There are several suggested methods for eliminating difficulty from footing drains, as follows:

1. Enforce the prohibitions against connecting floor and footing drains to sanitary sewers. This has proven very difficult, especially after houses are completed. It will usually require installing a sump and pump to discharge these flows to the street gutters. FHA is now insisting on this in certain low areas for new houses. Building codes should be revised to prohibit connection of footing drains to sanitary sewers.

2. Eliminate cellar floor and footing drain from the house. This will require considerable steel reinforcing of the cellar floor and walls and is not recommended by builders or by Federal agencies which guarantee mortgages. The writer has observed an 8-in. floor slab raised 4 in. and cracked by water pressure, although reinforced in both directions with ⅜-in. rods.

3. Permit connection of footing drains and make sanitary sewers large enough to carry the additional flow. This is impractical if the flow reaches the quantity previously stated for new construction, because a 3-ft. diameter sewer would be required where an 8-in. one is now sufficient. However, it is doubtful that it will be possible to eliminate footing connections in all the places where they are now installed and provision of 3,000 to 5,000 g.p.d. extra capacity per house should be considered in proposed systems.

Infiltration tests of all sewers under supervision of the owner or consulting engineer should be mandatory. They

must be preceded by inspection during construction to make sure pipe is well bedded and joints are complete and tight. The manner of making house connections may be a big source of trouble and should also be closely watched.

Additional studies are needed to determine the peak flows on laterals where footing drains are connected. Some work on this problem is being done by one consulting engineer in Erie County.

New Systems

In view of the difficulties outlined, it is believed that sewer systems for residential communities should be planned in the future to include some footing drainage. At the same time measures must be taken to limit this ground-water flow by careful supervision of the construction of house basements. Backfilling around cellar walls should be of selected material properly compacted and the ground should slope away from the house.

It further appears that there may be valid reasons for considering some type of combined sewers in some new residential communities. The need for making provision for drainage of ground water and surface runoff, as well as sanitary sewage, is frequently well established. Few communities can now make financial provision for separate systems and it is doubtful if the costs of such double construction are always justifiable because of the public health considerations involved. The wording of the New York State Water Pollution Control Act and its classification system, referring to reasonable standards of quality for streams, seems to indicate that a combined sewer system with overflows to the stream during storm periods is permissible for certain conditions and that it may represent the most economical solution. It would, of course, increase the difficulty of maintaining minimum velocities in dry weather. It appears that the decision regarding the type of system should be made by the consulting engineer, based on local drainage needs and cost considerations, and that if a combined system is selected, adequate protection of the stream is still possible. However, the widespread agreement among health departments that only separate systems should be permitted requires close examination of this suggestion.

It is probable that even where sanitary sewers are installed they will often continue to be used as combined sewers, and this fact will influence the success of pollution abatement measures. In one Erie County community the complete treatment plant has an efficiency of only 65 per cent and the sanitary sewers overflow continuously to the stream at various points. Nevertheless, the stream meets the required D classification of the New York Water Pollution Control Act except for the presence of occasional visible floating solids. There is a need to improve and extend understanding of the effect which storm overflows have on receiving streams.

Palmer (2) points out that the operational problems involved in maintaining a separate system as such have not been successfully solved, particularly in the larger systems. He states that sanitary connections improperly find their way into storm sewers, and storm connections into sanitary sewers, and concludes that costs of separate systems are prohibitive and not commensurate with the results possible to achieve. As a part of his study, samples of storm-water runoff from the land surface were collected at catch basins and compared with the quality of overflows from combined sewers, with the approximate results shown in Table II. It is probable that the characteristics of both types of drainage will be erratic, but that both may influence stream pollution during storm runoff.

Drury (3) also emphasizes the many difficulties in the construction and use

TABLE II.—Approximate Analysis of Surface Runoff and Combined Overflow

Sample	M.P.N.	5-Day B.O.D. (p.p.m.)	Total Vol. Sol. (p.p.m.)	Susp. Sol. (p.p.m.)
Storm water	500,000	150	300	—
Combined sewer overflow	4,000,000	50	—	250

of separate sewers and the economy inherent in combined systems. The latter type also permits some treatment of the first flush of solids from streets, which may be important when the receiving stream is small. He refers to a combined system for Midland, Mich., that appears to operate satisfactorily and is designed to handle sanitary sewage and runoff from roofs, but not from streets.

Metcalf and Eddy (4) state that separate sewers are often adopted without a thorough study of the comparative merits of separate and combined systems. They also emphasize the annoyance and damage which result from storm and ground water reaching sanitary sewers, pointing out that the effect of these abuses increases as the system grows older. They describe one city which was compelled to double the size of its treatment plant, due to the entrance of ground water into the separate system. One of the most important sources of this water was believed to be drainage from wet cellars. They conclude by questioning how long such conditions may be tolerated without justifying the conclusion that the separate system in any case is a failure.

In England and Germany, where available dilution is apt to be small, it has long been the practice to utilize combined sewers and to give treatment to storm water up to about six times the dry-weather flow. In the United States, interception of 2 to 3 times the dry-weather flow is usually practiced, with indications that treatment of higher amounts of storm water are not justified by the increasing amount of pollution control secured.

Hess and Manning (5) Akerlindh (6), and Theroux and Meek (7) have recently proposed methods for determining the amount of combined sewage which should be diverted to treatment in order to keep pollution of the stream within prescribed limits.

Akerlindh (6) demonstrates that a mutual interdependence often prevails between the amount of storm flow diverted for treatment and the required degree of treatment for the dry-weather flow, and that this problem must be evaluated separately for the bacteriological and biochemical effects on the stream. In other words, total pollution is the sum of treatment plant discharge plus occasional overflows or discharge from storm drains.

It is not the intention here to minimize the difficulty of determining in advance the effect which overflows from combined sewers will have on the receiving stream, but to outline certain conditions indicating that combined sewers do not significantly conflict with programs for stream pollution abatement. The type of effect which overflows have may be shown by the following example: If the discharge from a storm overflow is expressed as q_1, the dry-weather flow as q_2, and the flow in the system due to precipitation as q_3, then

$$q_4 = q_3 + q_2 - rq_2$$

where rq_2 is the flow diverted for treatment.

With a population density of 10 per acre at a per capita flow of 100 g.p.d., the dry-weather flow is equivalent to the runoff produced by a rainfall intensity of 0.003 in. per hour after land surfaces are wetted and where the time

of concentration is 30 min. It has been shown (2) that runoff to sewers does not usually occur until precipitation exceeds 0.03 in. per hour. Therefore, if $r = 3$, a surplus discharge equal to the dry-weather flow will occur for a storm with an intensity of 0.039 in. per hour. For successive increments in rainfall intensity, it is possible to compute the resulting overflow q_4 for storms of 1-hr. duration as shown in Figure 1. It is generally agreed that the most significant pollutional effect on the stream will result from low-intensity storms, especially those of considerable duration.

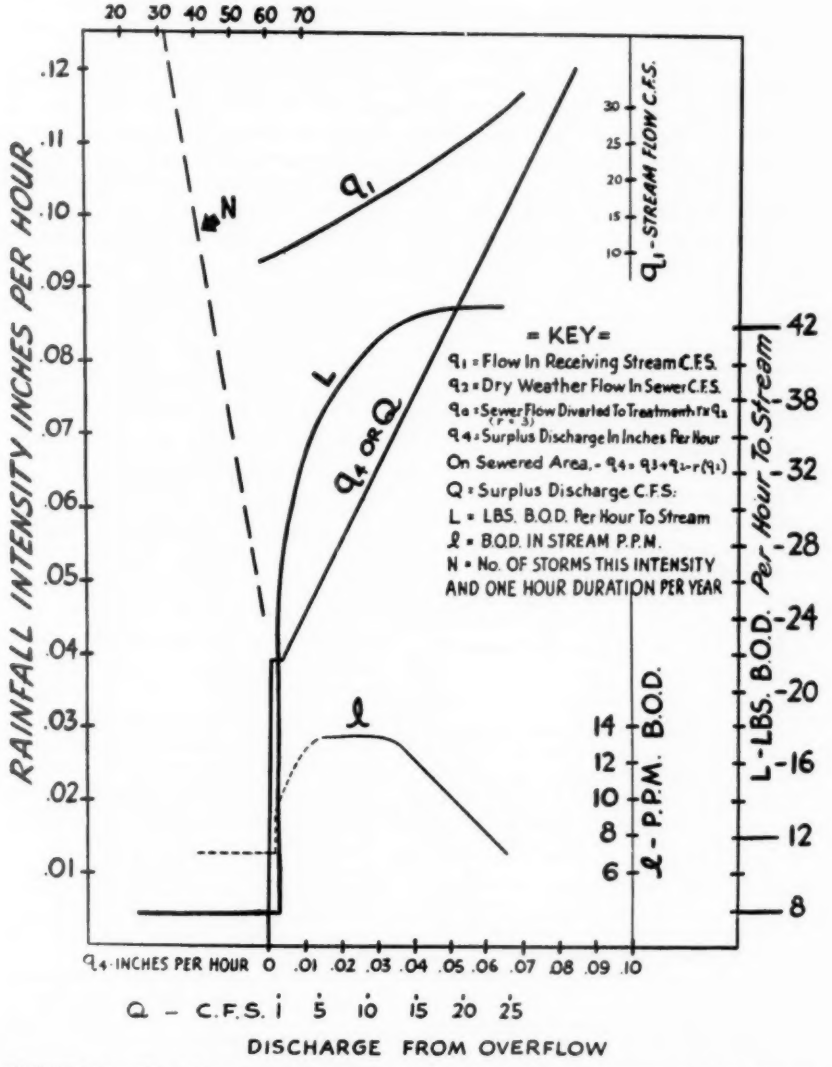
RAINFALL INTENSITY INCHES PER HOUR
20 30 40 50 60 70
.12 .11 .10 .09 .08 .07 .06 .05 .04 .03 .02 .01
N
q_1
L
q_4 OR Q
l
q_1 - STREAM FLOW C.F.S.
30 25 20 15 10
= KEY =
q_1 = Flow In Receiving Stream C.F.S.
q_2 = Dry Weather Flow In Sewer C.F.S.
q_3 = Sewer Flow Diverted To Treatment $(r = 3)$ q_2
q_4 = Surplus Discharge In Inches Per Hour On Sewered Area, - $q_4 = q_3 + q_2 - r(q_2)$
Q = Surplus Discharge C.F.S.
L = LBS. B.O.D. Per Hour To Stream
l = B.O.D. IN STREAM P.P.M.
N = No. OF STORMS THIS INTENSITY AND ONE HOUR DURATION PER YEAR
l - P.P.M. B.O.D.
14 12 10 8 6
L - LBS. B.O.D. Per Hour To Stream
42 38 32 28 24 20 16 12 8
q_4 - INCHES PER HOUR 0 .01 .02 .03 .04 .05 .06 .07 .08 .09 .10
Q - C.F.S. 1 5 10 15 20 25
DISCHARGE FROM OVERFLOW

FIGURE 1.—Chart for computing resulting sewage overflow for storms of 1-hr. duration and various intensities.

On Figure 1 has also been shown the number of 1-hr. storms of various intensities expected each year at Buffalo, N. Y., as reported by Carstensen and other investigators of the Buffalo Sewer Authority.

Also indicated on Figure 1 is the probable effect on a small stream in Erie County due to a combined sewer system and secondary sewage treatment plant serving 7,500 persons. The total B.O.D. loading on this stream in pounds per hour, and the resulting initial concentration of B.O.D. in p.p.m. is shown for various amounts of overflow, assuming uniform mixing in the sewers and stream.

Although Figure 1 is not held to have general applicability, it appears that for the stated conditions the most critical loading on the stream will be caused by rainfall intensities from 0.05 to 0.07 in. per hour for storms of 1-hr. duration. Such conditions can be expected four to five times a month. Storms of greater duration and the same intensity would be more significant but occur less frequently.

Experience in Western New York indicates that such occasional overflows resulting from storms are not likely to cause serious oxygen depletion in streams. It may be that suspended solids and bacteria reaching streams through overflows will be of greater significance than B.O.D. These factors are more easily subject to control, however, by sedimentation and chlorination of the overflow when necessary. Where the stream is not used for water supply or bathing the most objectionable conditions noted due to overflows are visible floating solids.

McKee (8) states that if twice the dry-weather flow is intercepted, less than 3 per cent of the domestic sewage escapes in overflows which occur only five to six times per month and which will not have a significant effect on pollution. He adds that increasing the diversion to 10 times the dry-weather flow will only cut the frequency of overflow to three per month.

It is concluded that combined sewers adequate for controlled amounts of ground and surface water are economically desirable in some new residential areas, and that such systems can be designed to meet the requirements of pollution abatement programs and public health.

Acknowledgments

The assistance of M. J. Stankewich, Chief, Bureau of Water and Sewage Control, Erie County Department of Health, and the district engineers of the department in the preparation of this paper is gratefully acknowledged.

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COMPARATIVE STUDIES OF THE DILUTION AND WARBURG METHODS FOR DETERMINING B.O.D.*

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Since its introduction by Caldwell and Langelier (1) in 1948, the Warburg constant-volume technique has come to be regarded as the most useful of the manometric methods for B.O.D. determinations. Caldwell and Langelier, however, as well as other investigators (2)(3)(4)(5), call attention to the difficulty of interpreting results obtained by the manometric technique because they are not strictly comparable to those obtained by the "Standard Method" (6) dilution method.

The studies herein reported were undertaken for the purpose of obtaining data from which a more accurate relationship between results of B.O.D. determinations by the two methods might be established. They involved the simultaneous application of the Warburg technique and the dilution method to a number of liquid wastes under as nearly identical conditions as could be obtained without significantly altering either procedure. The deoxygenation constant, k, the first-stage B.O.D., L, and the lag period were the parameters chosen for comparison, and efforts were made to discover the possible origin of the observed difference in values of these parameters as obtained by the two methods. At the same time, the Warburg technique was critically examined both from the standpoint of its cost and its utility as a routine testing procedure for the analytical laboratory. Observations were performed in duplicate and a total of 130 sets of comparable data were obtained by the two methods.

Materials and Methods

Five major variables were, within practical limits, held constant during the comparative B.O.D. tests. These were used in parallel experiments involving the two testing techniques. As shown in Table I, five experiments were run with fresh domestic sewage; two with synthetic sewages (7)—one fresh and one sterile; four with sterile domestic sewage; and two with solutions of standard glutamic acid (8). Domestic sewage which had been sterilized in the laboratory was utilized because in studies of algal-bacterial symbiosis it had proved capable of maintaining a reasonably constant B.O.D. for at least two years (9) when properly bottled and stored. Glutamic acid and synthetic sewage were included because of a recent widespread interest in such materials as a possible source of constant sewage in research. Fresh domestic sewage was employed because it may differ greatly in B.O.D. characteristics from sterile or synthetic sewages and because of its importance in problems of waste disposal.

Seeding Material

Two types of seeding material were used—fresh sewage and frozen sewage (5)—as shown in Table I. Frozen sewage seed was used in the first experiments because of the desirability of holding the factor of seeding ma-

* Presented at 1953 Annual Meeting, California Sewage and Industrial Wastes Assn.; Santa Barbara, Calif.; April 22–25, 1953.

TABLE I.—Outline of Comparable B.O.D. Tests Performed Simultaneously by the Dilution and Warburg Techniques

Test No.	Type of Sewage	Source of Sewage	Type of Seed
1	Fresh domestic	Richmond City	Fresh sewage
2	Fresh domestic	San Pablo City	Fresh sewage
3	Fresh domestic	East Bay Munic. Util. Dist.	Fresh sewage
4	Fresh domestic	S.F. Richmond-Sunset Dist.	Fresh sewage
5	Fresh domestic	S.F. North Point District	Fresh sewage
6	Fresh synthetic	See Ref. (7)	Fresh sewage
7	Sterile synthetic	See Ref. (7)	Fresh sewage
8	Sterile domestic	S.F. Richmond-Sunset Dist.	Frozen sewage
9	Sterile domestic	S.F. Richmond-Sunset Dist.	Frozen sewage
10	Sterile domestic	S.F. Richmond-Sunset Dist.	Frozen sewage
11	Sterile domestic	S.F. Richmond-Sunset Dist.	Frozen sewage
12	300 p.p.m. glutamic acid	See Ref. (9)	Frozen sewage
13	300 p.p.m. glutamic acid	See Ref. (9)	Frozen sewage

terial constant throughout the study. As pointed out by Sawyer *et al.* (8), the need for eliminating seed as a variable in B.O.D. studies is very great. It was found, however, that an objectionable lag period was introduced by the use of frozen seed, hence in some of the later experiments fresh sewage seed was utilized.

Dilution Water

Dilution water was held constant throughout the experimental work except in the glutamic acid tests, where a pH adjustment was made to determine its effect. The dilution water was prepared by adding "Standard Methods" solutions A, B, C, and D to distilled water in the recommended amounts. The distilled water contained less than 0.001 p.p.m. of copper. This dilution water, made up in 19-l. lots, was aged at 25° C. for at least one week, but not more than two weeks. The water was aerated for 4 hr. and "rested" for 12 hr. prior to use. Just before starting a series of tests, a volume of seed suspension amounting to 0.2 per cent by volume was added and dispersed in the dilution water.

Temperature and Time of Incubation

Throughout the experiments a holding temperature of 25° C. was maintained for both techniques. This was the lowest practicable constant temperature at which both techniques could be performed with the available equipment. Comparable tests involving daily measurements were run simultaneously, and generally were continued for at least 10 days.

Experimental Techniques

In the Warburg tests the techniques recommended by Ludwig *et al.* (5) were followed. Two ml. of the samples and 2 ml. of the dilution water-seed suspension were used. In the dilution tests, the techniques recommended in "Standard Methods" were followed except a temperature of 25° C. was substituted for the recommended 20° C. As previously mentioned, duplicate determinations were made in both techniques. The average of these two values was reported as the observed B.O.D. For incubation periods up to 10 days, duplicates generally differed by less than 5 per cent in the Warburg tests and by less than 10 per cent in the "Standard" dilution tests.

Although identical substrate, seed, dilution water, temperature, and incubation time were used in each of the comparable tests, the relative concentrations of three of these factors (that is, seed, diluting water, and sewage) are inherently different in the two methods. Table II presents a compari-

son of the ratios of volume of each factor to the total test volume, and shows that the ratio of seed suspension volume to total test volume was the only identical component in the two methods. The ratio of seed volume to sewage volume and of sewage volume to total test volume were fixed at different values because of the basic difference in the two methods.

The ratio differences indicated in Table II must, within limits, be considered inherent differences in the two techniques. Thus, the comparison of the two techniques is a practical rather than an absolute one.

TABLE II.—Ratios of Primary Components in Comparative Tests

Ratio of Component Volumes	Dilution Technique	Warburg Technique
Seed volume to total test volume	0.002	0.002
Sewage volume to total test volume	0.016	0.500
Seed volume to sewage volume	0.12	0.004

Results

Magnitude of k *and* L

The magnitude of the first-stage reaction velocity, k, the ultimate first-stage demand, L, and the lag periods for the comparable Warburg and dilution experiments on the 13 different substrates shown in Table I are summarized in Table III. The values shown were calculated from the observed daily oxygen depletions by the "slope method."

As has been found by several investigators, the values of k were somewhat larger than usually expected at 25° C. This might be due to the relatively large amounts of colloidal and dissolved organic material in the filtered sewage used in the experiments, as compared to normal unfiltered sewage. Some of the reasons for large k values for filtered sewage have been pointed out by Heukelekian (3)(11). The values of k for the five experiments with domestic sewage were approximately the same for the dilution and Warburg techniques, the average Warburg k being 0.030 higher than the average dilution k. The Warburg k is the higher for the fresh synthetic

TABLE III.—Comparison of k, Lag Period, and L for Dilution and Warburg Methods

Experiment Number	Type of Sewage	Reaction Rate, k		Lag Period (days)		Ultimate[1] B.O.D., L (p.p.m.)	
		Dilution	Warburg	Dilution	Warburg	Dilution	Warburg
1	Fresh domestic	0.305	0.298	—	—	170	195
2	Fresh domestic	0.336	0.287	—	—	101	109
3	Fresh domestic	0.384	0.365	—	—	128	135
4	Fresh domestic	0.148	0.255	—	—	130	143
5	Fresh domestic	0.266	0.393	—	—	215	239
Av.	—	0.289	0.319	—	—	—	—
6	Fresh synthetic	0.204	0.264	—	—	193	205
7	Sterile synthetic	0.848	0.355	—	0.79	149	188
8	Sterile domestic	0.524	0.689	—	0.81	116	142
9	Sterile domestic	0.824	0.659	—	0.94	142	161
10	Sterile domestic	0.446	0.450	—	0.32	125	131
11	Sterile domestic	0.278	0.235	—	0.26	53	73
Av.	—	0.518	0.508	—	—	—	—
12	300 p.p.m. glutamic acid sol.	1.782	0.469	—	0.91	135	166
13	300 p.p.m. glutamic acid sol.	2.230	0.512	—	0.79	126	165

[1] Theoretical.

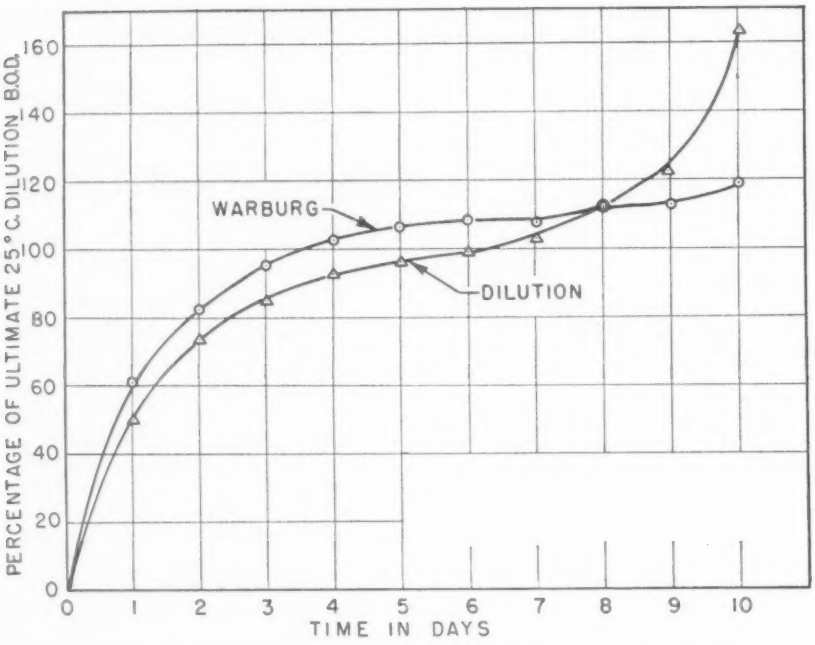

FIGURE 1.—Comparative Warburg and dilution B.O.D. curves for five fresh domestic sewages.

sewages, but much lower than the dilution method k for the sterile synthetic sewage. The average k values for the four tests on sterile domestic sewage and frozen seed were approximately the same for both methods. The dilution method k values were much higher than the Warburg for the 300 p.p.m. glutamic acid. [This was undoubtedly caused by the higher initial pH (7.2) in the well-buffered dilution bottles as compared to the low pH (4.3) in the Warburg.]

TABLE IV.—Ratio of Warburg to Dilution B.O.D. at 25° C. for Fresh Domestic Sewage

Days After Start of Experiment	Ratio: $\frac{\text{Warburg}}{\text{Dilution}}$
1	1.22
2	1.11
3	1.07
4	1.10
5	1.10
6	1.09
7	1.06

The values of ultimate first-stage demand, L, for all 13 sewages averaged 15 per cent higher for the Warburg than for the dilution technique. The Warburg L values averaged 10 per cent higher for the five fresh domestic sewages with fresh seed and 19 per cent higher for the four sterile domestic sewages with frozen seed. The Warburg L was about 6 per cent larger for fresh synthetic sewage, 26 per cent larger for sterile synthetic sewage, and averaged 27 per cent larger for the glutamic acid solutions. In general, the ratio of Warburg to dilution values of L appears to be larger when there was a considerable lag in the Warburg oxidation curve.

To simplify plotting the data, the average value of daily duplicate determinations of the B.O.D. was calculated as a percentage of the first-stage

L value for the dilution method of the corresponding sewage as in Figures 2 and 3. When several sewages of the same type were analyzed (Figures 1, 4, and 5), the average daily B.O.D. values in terms of per cent of L for all samples were plotted, thereby providing a single curve for each technique.

Experiments with Fresh Sewage Seed

The average oxygen uptake of fresh domestic sewage with fresh sewage seed, as determined by the Warburg and the dilution methods, is shown in Figure 1. The Warburg values of 25° C. B.O.D. averaged about 10 per cent higher than those obtained by the dilution method until after the seventh day (Table IV).

After six to eight days at 25° C., the dilution B.O.D. enters the nitrification stage and the B.O.D. exceeds that of the Warburg. The Warburg seldom shows a second stage, probably because the CO_2 adsorption causes the pH to become too high for nitrification to take place.

The fresh synthetic sewage curves (Figure 2) indicate a relationship similar to that of the fresh domestic sewage during the first stage. Each curve represents one experiment instead of an average of five as in Figure 1, which may account for the somewhat greater variation of observations from the fitted curve. The dilution sample did not exhibit a second stage, although the Warburg sample showed a small increase after the eighth day.

The B.O.D. curves for sterile synthetic sewage and for fresh sewage seed are shown in Figure 3. A comparison of these curves with those in Figure 2 reveals that the effect on the 25° C. B.O.D. of sterilizing synthetic sewage is quite pronounced. There is a lag period of 0.79 days in the Warburg, after which oxidation takes place with a smaller k but with a greater B.O.D. after the third day, which reaches a maximum excess of 17 per cent on the sixth day. Thereafter the dilution sample entered the nitrification stage and, as before, exhibited a

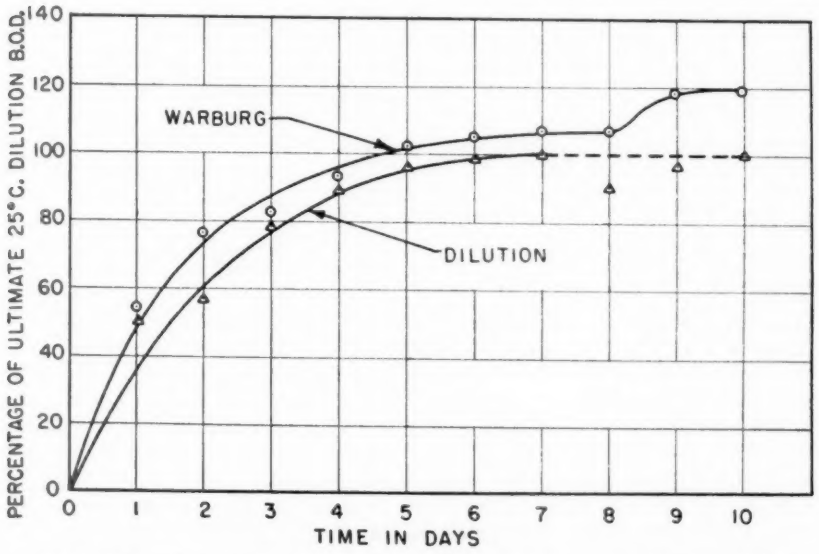

FIGURE 2.—Comparative Warburg and dilution B.O.D. curves for unsterilized synthetic sewage.

greater rate of oxygen uptake than the Warburg sample.

Sterilization of the substrate was the only difference in the experiments summarized in Figures 2 and 3; it must be concluded, therefore, that the profound difference in the two sets of curves is the result of sterilization. It has been observed that sterilization of either synthetic or domestic sewage will increase the pH from 1 to 1.5 units, and that in addition, some colloidal material is coagulated and precipitated. Such a pH change will produce a greater effect in the Warburg test than in the dilution test, since the buffer capacity of the diluting water is more effective in the more dilute bottle mixture. Inasmuch as there was no apparent lag in the dilution tests of fresh and sterile synthetic sewage, or the Warburg test on fresh synthetic sewage, it appears that the Warburg lag for sterile synthetic sewage was due primarily to the higher pH and the destruction of any organisms which might have been present in the fresh synthetic sewage during preparation. As shown in Table III, the first-stage demand of the synthetic sewage was considerably reduced by sterilization.

Experiments with Frozen Seed

The average B.O.D. curves for the four sterile domestic sewages with frozen seed are shown in Figure 4. The Warburg curve again exhibits a lag period, followed by a quick rise to B.O.D. values greater than those of the dilution sample. As in the case of substrates seeded with fresh sewage seed, there was no significant tendency of the Warburg sample to enter a second stage. The dilution sample appears to have been inhibited by some factor also, and the curve rises only slightly at the time the nitrification stage would normally begin. If this factor is high pH in the case of the Warburg sample, it is logical to presume that the increase in pH due to sterilizing domestic sewage was in this case sufficient to inhibit the B.O.D. of the dilution sample. The lag period

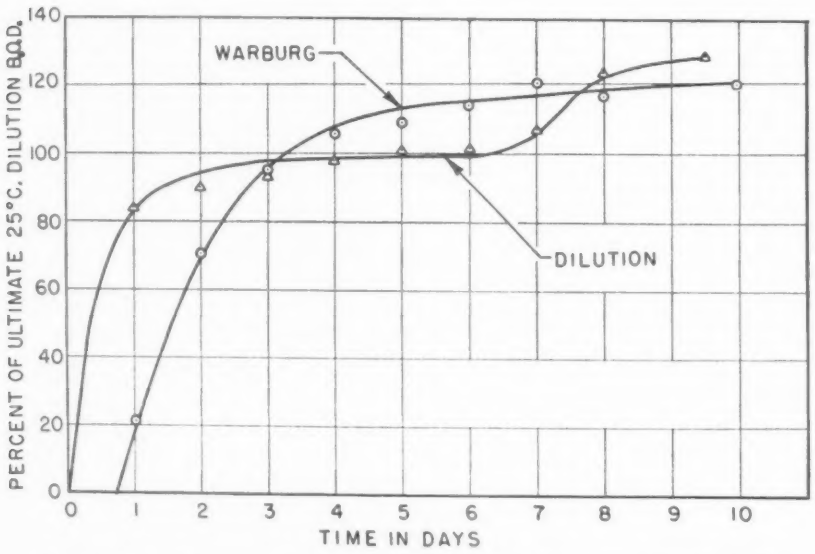

FIGURE 3.—Comparative Warburg and dilution B.O.D. curves for sterilized synthetic sewage.

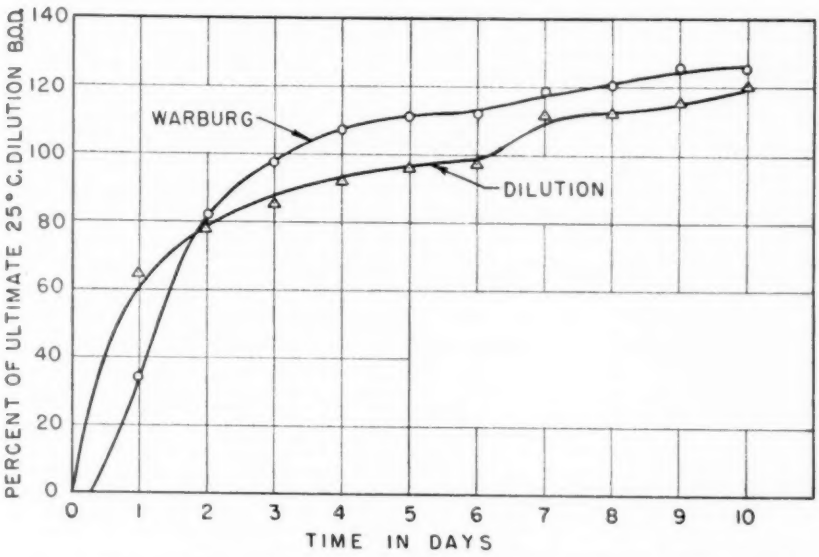

FIGURE 4.—Comparative Warburg and dilution B.O.D. curves for four sterile domestic sewages.

for the Warburg curve is typical for Warburg B.O.D. results on sterile sewage and frozen seed. Since the value of the Warburg B.O.D. is higher than the dilution, it is apparent that there was sufficient seed eventually to oxidize the organic matter. Many independent tests not reported herein have shown that the lag period for sterile domestic sewage is not eliminated by utilizing fresh sewage seed, although it can be diminished considerably. One factor contributing to the lag is the small amount of seed with respect to the amount of sewage when the same seeded dilution water is used for both the dilution and Warburg techniques.

The average results for the two experiments with glutamic acid and frozen sewage seed are shown by the curves of Figure 5. The ratio of Warburg to dilution B.O.D. during the flat portion of the curves is approximately constant. Even though seeding and conditions in the Warburg test were not adequate to prevent a large lag period or to provide a larger value of k, the ultimate first-stage B.O.D. values for the Warburg tests were greater than for the dilution tests. The ultimate first-stage B.O.D. of the 300 p.p.m. glutamic acid and frozen seed is much less than the 217 ± 10 p.p.m. at 20° C. reported by Sawyer (8) when adequate seed was present. Similar results have been obtained from other tests with glutamic acid and frozen seed, while well-seeded tests give B.O.D. values similar to Sawyer's.

Considerable additional investigation is necessary to determine the adequacy of frozen sewage as a source of a constant seed material. One of the undesirable effects of freezing sewage for seed is the die-away of organisms which takes place on freezing and which continues during storage. This reduction by freezing could result from a general kill and over-all loss in the number of organisms, or from a selective killing of certain species. In the latter case, a small sample from a highly diluted aliquot of frozen seed material might contain only the dominant spe-

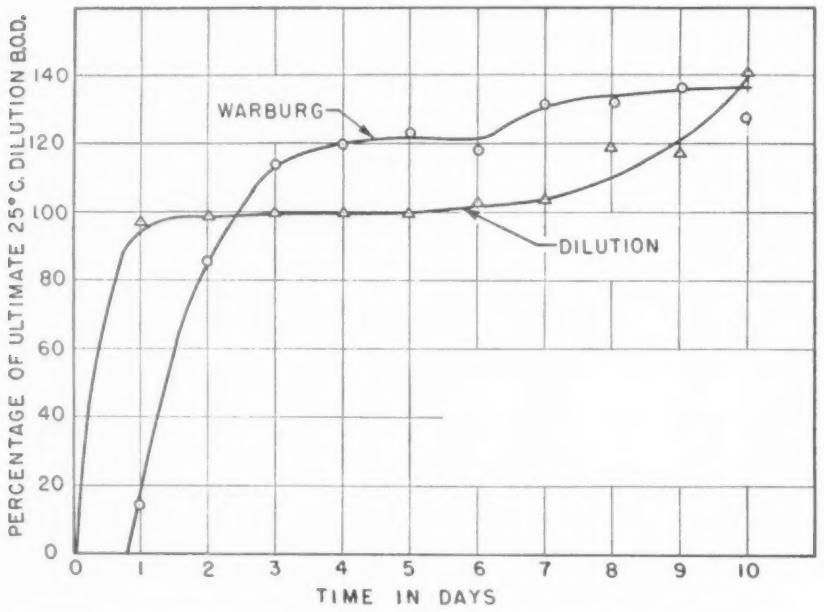

FIGURE 5.—Comparative Warburg and dilution B.O.D. curves for two glutamic acid (300 p.p.m.) solutions.

cies originally present. Since a variety of different species of organisms will oxidize more components of a given waste than a few species, and since the B.O.D. was higher for the Warburg with more dilute seed, it appears that there were adequate numbers of species in the Warburg test as well as in the dilution tests, but that the Warburg seed was low in absolute numbers of bacteria.

It is evident that the lag periods observed for sterile sewages and glutamic acid tested by the Warburg technique were due not only to the dilute frozen seed, but also to a slightly adverse hydrogen ion concentration to which the seed organisms must adapt. The relatively small volume of phosphate buffered dilution water used in the Warburg flasks (2 ml. of dilution water-seed mixture and 2 ml. of sample) does not provide sufficient buffer capacity as compared with the standard dilution technique, which uses 300 ml. dilution water-seed mixture and about 5 ml. of sample (see Table II). It has been observed in many Warburg tests that the pH of the mixture rises above 9.5 in the course of a 5-day test. Water blanks run simultaneously with these tests do not increase in pH, indicating that the increase is not due to accidental spillage or "creep" of the alkaline CO_2 absorbent. A similar pH increase is present in tests where dry soda lime, which could not spill, was used as a CO_2 absorbent. It appears that biological oxidation accompanied with CO_2 absorption in the Warburg destroys the small residual buffer capacity of the sample, resulting in an increase in the pH.

Figure 6 shows typical results with the Warburg technique for glutamic acid with an original low pH of 4.3, and after adjusting the pH to 7.0. Adjusting the pH seems practically to eliminate the lag period, but it also produced a considerable reduction in the B.O.D.

The glutamic acid with no pH adjustment shows a secondary B.O.D. rise, whereas the oxygen uptake is inhibited when the initial pH was adjusted to 7.0. The absence of a second stage in the adjusted pH sample appears to be due to the high pH (9.0 to 10.0), reached after 5-day incubation, which is known to be inhibitive to nitrification (10). During the first five days of a Warburg test, the pH of the substrate will rise as much as 3 or more pH units. The unadjusted glutamic acid, starting at pH 4.3, will rise to between pH 7.0 and 8.0, while the sample adjusted to pH 7.0 will attain pH 9.5 or higher. Hence, in Figure 6, the unadjusted glutamic acid was in a pH range of 7.0 to 8.0 after 6 or 7 days, which was satisfactory of nitrification, while the pH of the adjusted glutamic acid was 9.5, which was too high for nitrification. If the adjusted pH sample had been sufficiently buffered to maintain a pH of 7.0, probably a second stage would have occurred.

Experiments in progress indicate that the Warburg lag period may be largely overcome by increasing the amount of seed used and by increasing the buffer capacity of the system. Seed volumes equal to 1 per cent of the dilution water, and double-or triple-strength buffer in the dilution water, are being used. However, seeding must be kept to a minimum so that the B.O.D. of a waste will not be changed. Control of the pH rise in the Warburg method constitutes a major problem in developing this technique to general usage.

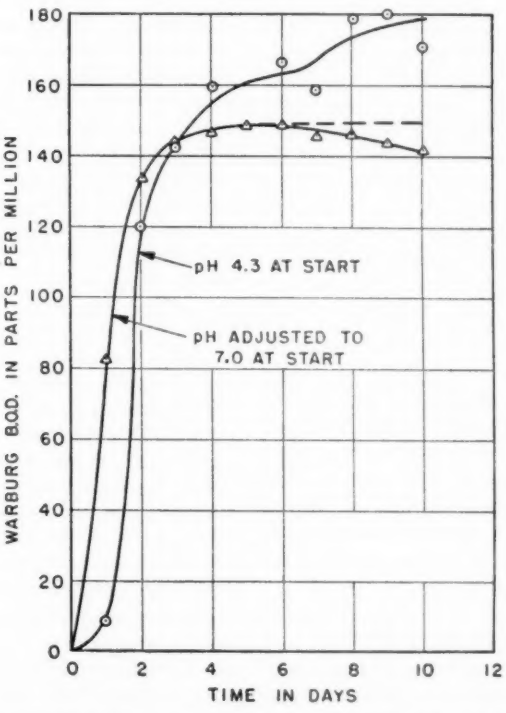

FIGURE 6.—Comparative Warburg B.O.D. curves for adjusted and unadjusted pH of glutamic acid (300 p.p.m.) solutions.

Depressions in Warburg B.O.D. Curves

The depression of the Warburg B.O.D. curve after the fifth to seventh day of incubation, as shown for the adjusted pH glutamic acid of Figure 6, is typical, and represents a frequently occurring phenomenon which warrants further study. Present data do not explain the causes of this depression of the B.O.D. curve. Since flasks containing seed and dilution water are used as control barometers in the Warburg method, and since these control barometers are used to determine manometric deflection in the test flasks, it is possible that endogenous respiration of the seed organisms could at least partially account for the appearance of a "negative" oxygen uptake. Another possible source of this effect could be the release from the liquid of small amounts of some gas. This is possible because of the large surface area-volume relationship that exists in the Warburg, together with the violent agitation to which the liquid is subjected. Since there is some indication that nitrification starts in the Warburg during the normal carbonaceous stage when the pH is not inhibiting, and then ceases as the pH increases to inhibiting magnitude, it may be that some of the nitrified material is reduced, resulting in a "negative" oxygen uptake. Of these explanations, it would seem most probable that endogenous respiration of the seed organisms in the control flask is the most likely. More work, however, is needed on this particular phenomenon, because it would seem to offer an unusual opportunity for a greater understanding of the transient conditions which lead ultimately to the oxidation of ammonia.

Comparison of Methods

An evaluation of the comparative merits of the Warburg and dilution methods involves the consideration of some six factors, as follows:

1. Laboratory space required.
2. Initial, maintenance, and operational costs of necessary apparatus.
3. Technical skill required to perform tests.
4. Time required to perform tests.
5. Significance of results obtained.
6. The relationship between results by the two methods.

Laboratory Space

In the experiments herein reported, the amount of laboratory space required for apparatus was found to be approximately the same for both methods. The capacity of the equipment, however, differs greatly. The number of samples that can be handled daily without interruption in the Warburg is very limited. For example, a 20-place apparatus used for normal 5-day B.O.D. tests will take only two new samples per day if samples are run in duplicate. This is a major limitation of the Warburg apparatus in laboratories that must run many routine samples daily. When a considerable number of points on the B.O.D. curve are desired, however, the space devoted to dilution tests increases with the number of points, whereas the space devoted to Warburg tests is independent of the amount of detail desired.

Costs

The initial cost of equipment for the two methods is, of course, a function of its capacity. In general, it might be said that the apparatus for Warburg tests costs approximately twice as much as that used in the dilution method. Its maintenance is likewise much more costly. Operational costs are largely a function of the amount of detail required on the B.O.D. curve. If only a single 5-day observation on the oxygen uptake curve is required, the dilution method should be appreciably cheaper. On the other hand, if many points are required, a single Warburg test may produce data that would

call for a great number of dilution bottle tests.

Technical Skill and Time Required

No significant difference has been noted in the skill required in the laboratory performance of either technique, as both require a degree of technical proficiency which can be developed only through considerable experience. The time spent per unit test setup is about the same by either method, and the amount of detail required ordinarily determines which technique requires the most time in a particular study. Based upon experimental work involving daily duplicate points for 10 successive days, the Warburg required about one-tenth of the time to obtain equivalent data by dilution technique.

Significance and Relationship of Results

All B.O.D. tests, regardless of technique, have a common limitation in applying test results to predicting what will take place when the waste is actually oxidized in a different environment, such as a stream. The results from dilution tests are less limited in this respect because results from these tests have been applied to practical problems for many years. The utility of the Warburg in yielding detailed data may offset the disadvantage of lacking long experimental background if a relationship between the results of the two methods were established. The large number of points on oxidation curves obtainable with the Warburg readily show transient phenomena such as lag periods, second-order oxidative stages, and the onset of nitrification. Similar data utilizing the dilution method are obtainable only through long and time-consuming experiments with a large number of individual bottle tests.

Summary and Conclusions

1. Comparable tests have been performed to determine the relationship between the Warburg B.O.D. and the dilution B.O.D. Results indicate the values of ultimate first-stage demand, L, averaged about 15 per cent higher for the Warburg than the dilution technique. The values of reaction rate, k, of fresh and sterile domestic sewage were approximately the same for the dilution and Warburg techniques.

2. Frozen sewage seed as a source of constant seed material for B.O.D. determinations is not yet completely satisfactory and requires further investigation, since die-away of bacteria appears to take place on freezing and continues through the storage period.

3. The small quantities of "Standard Methods" dilution water used in the Warburg technique does not buffer the higher pH of sterilized sewage or the effect of CO_2 absorption on the pH of the solution. The initial higher pH contributes to the lag period, and the further increase in pH during incubation inhibits nitrification. A highly buffered dilution water specifically designed for Warburg manometric B.O.D. determinations should be developed.

4. The Warburg test, when applied to sterile wastes, is particularly sensitive to seed and nutrient relationships. The occurrence of lag periods may be indicative of insufficient seeding, either in number or variety of organisms. Thus, for samples that must be seeded, relatively large volumes of seed are added to the diluting water to insure that proper seeding is attained. Lag periods may rule out the possibility of using short-term Warburg results for industrial wastes or other wastes of unknown character, requiring that the test be carried on for at least three days, and preferably five days, if reliable results are to be obtained.

5. When a large number of routine B.O.D. samples must be tested daily the Warburg is not an applicable instrument because of its limited capacity. As the number of required points on the B.O.D. curve increases, the space devoted to dilution test in-

creases, whereas the space devoted to Warburg test is independent of the amount of detail desired. The Warburg can be used to measure wastes having a wide range of strengths with one test, while a number of dilutions of one waste may be required to determine the strength by the dilution method.

6. An evaluation indicates that the equipment and maintenance cost for the Warburg method may be as high as ten times as much per test as those of the dilution method. If many points are required on an oxygen uptake curve, a single Warburg test may suffice to produce the data, but many dilution bottle tests must be required.

7. No significant difference has been noted in the technical ability required in the laboratory performance of either techniques as both require a degree of technical proficiency, which can be developed only through considerable experience. The time spent per unit test setup is about the same by either method and the amount of detail required ordinarily determines which technique requires the most time in a particular study.

8. Because of application to practical problems in the past, the dilution tests are presently less limited than the Warburg. The large number of points on an oxidation curve obtainable with the Warburg readily shows transient phenomena, such as lag periods, second-order oxidation stages, and the onset of nitrification.

Acknowledgments

The authors are indebted to Professors H. B. Gotaas, W. F. Langelier, and E. A. Pearson, and Mr. P. H. McGauhey, of the University. Their assistance and advice have greatly facilitated the present work.

This research was conducted in conjunction with algal-bacterial research partially supported by a grant from the National Institutes of Health of the United States Public Health Service.

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Industrial Wastes

POLLUTION REDUCTION IN COTTON FINISHING WASTES THROUGH PROCESS CHEMICAL CHANGES *

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Although many investigations in the past have been made to determine the polluting power of textile wastes, little attention has been paid to the chemical compounds which actually exert the B.O.D. and which impart other polluting characteristics to the wastes. This phase of investigation is assuming more importance because of the accelerated activity of chemical manufacturers in producing many new synthetic chemicals for the processing of cloth. The increasing use of these chemicals is changing the characteristics of many mill effluents and a thorough study of their B.O.D. and other characteristics is long overdue.

The routine analytical survey of the individual wastes in a mill gives a good picture of the polluting power and volume of the wastes. However, no indication of the reasons why a considerable B.O.D. is or is not discharged in a particular rinse is obtained. No information is given on the proportion of B.O.D. contributed by the cotton fiber or by the process chemicals.

A considerable amount of this information may be obtained through an inventory and B.O.D. survey of the process chemicals actually used in the plant. Inventory data are usually available in practically all plants and may be readily obtained. Analysis for B.O.D. of the more important process chemicals can be made and can be the basis for calculation of the contribution of the individual chemicals to the total plant B.O.D. or to the particular waste in which it is discharged. Information may thus be obtained on the chemical constituents of the wastes, the major B.O.D. sources, the major B.O.D. discharges, possible methods of treatment, and possibilities of pollution reduction through substitution of process chemicals.

Inventory Survey

Such an inventory and B.O.D. survey was made in conjunction with an analytical survey (1) on a cotton finishing mill which processed fairly heavy cloth (0.56 lb. per yard). Of this cloth, 72 per cent was printed and 28 per cent was dyed.

By inspection of the plant inventory, the exact amount of all chemicals used in amounts greater than 1 lb. per 1,000 lb. of cloth was determined. Samples of all these chemicals were obtained and B.O.D. determinations were made where applicable. Part of these results, along with the calculated contribution in pounds of B.O.D. per 1,000 lb. of cloth, are recorded in Table I.

The most striking revelation indicated by the inventory survey was the enormous appetite of cotton finishing

* Presented at 25th Annual Meeting, New England Sewage and Industrial Wastes Assn.; Boston, Mass.; April 22–23, 1954.

TABLE I.—Cotton Finishing Process Chemicals, Consumption and B.O.D.

Chemical	Amount Used (lb./1,000 lb. goods)	B.O.D. (%)[1]	B.O.D. (lb./1,000 lb. goods)
B-2 gum	22	61	13.4
Wheat starch	16	55	8.8
Pearl cornstarch	14	50	7.0
Brytex gum No. 745	4	61	2.4
KD gum	4	57	2.3
Slashing starch	96[2]	—	53.0
Total	150	—	82.9
Carboxymethylcellulose	—	3	—
Hydroxyethylcellulose	—	3	—
Tallow soap	20–100	55[3]	11–55
Nacconal NR	1	4	.04
Ultrawet 35 KX	—	0	0
Acetic acid, 80%	27	52	14.0
Mixture of 18 dyes	37	7	2.6
Cream softener, 25%	20	39	7.8
Formaldehyde-bisulfite condensate	14	27	3.8
Glycerine	3	64	1.9
Sodium hydrosulfite	11	22	2.4
Urea	13	9	1.2
Finish T.S.	8	39	3.1
Kierpine extra	5	61	3.1
Merpol B	4	44	1.8
Glucose	—	71	—
Gelatin	—	91	—
Caustic, 76%	118	—[4]	—[4]
Soda ash	42	—[4]	—[4]
Ammonia	7	—[4]	—[4]
Potassium carbonate	3	—[4]	—[4]
Trisodium phosphate	2	—[4]	—[4]
Sodium perborate	3	—[4]	—[4]
Sodium silicate	6	—[4]	—[4]
Liquid soda bleach	4	—[4]	—[4]
Hydrogen peroxide	5	—[4]	—[4]
Sodium chloride	7	—[4]	—[4]
Sodium dichromate	6	—[4]	—[4]
Sulfuric acid	10	—[4]	—[4]
Hydrochloric acid	6	—[4]	—[4]

[1] Based on weight of chemical; for example, 1 lb. of B-2 gum (61 per cent B.O.D.) would require 0.61 lb. of oxygen for stabilization.

[2] Calculated from analytical survey.

[3] Apparently contained high water content; dry soaps averaged 130 to 150 per cent B.O.D.

[4] Negligible B.O.D. assumed.

mills for process chemicals. The results showed that a surprisingly high total of 750 lb. of chemicals was used to finish each 1,000 lb. of cloth.

Many of these chemicals have high B.O.D., and calculations revealed that they would contribute a total of 143 lb. of B.O.D. per 1,000 lb. of cloth. Of this, all but approximately 28 lb. incorporated in the finish size will be washed from the cloth during processing. In addition, as indicated by the analytical survey to be discussed later, about 40 lb. of B.O.D. was extracted from the cloth during scouring. The total B.O.D. discharged to the stream thus amounted to 155 lb. per 1,000 lb. of cloth, which checked fairly well with the 123 lb. determined by the analytical survey, when one considers sampling, measuring difficulties, and possible reactions.

Another important conclusion from the inventory survey was the high consumption and contribution of starch or modified starch compounds. The results showed that 150 lb. of six starch compounds were used for each 1,000 lb. of cloth. These averaged 55 per cent B.O.D. and contributed 56 per cent of the total plant B.O.D. Starch consumption is expected to be a little higher in the plant studied than in others because of its use for preparation of printing pastes. However, even if no printing at all were done, approximately 120 lb. per 1,000 lb. would have been used for slashing and finishing. Starch is therefore expected to be the major B.O.D. source in cotton finishing wastes.

Tallow soap also has a high pollution potential because of its high consumption and high B.O.D. During the course of this survey, the plant in question converted to the use of an alkyl aryl sulfonate detergent for washing and soap no longer was an important B.O.D. source. Calculations indicate, however, that it would have contributed 20 to 35 per cent of the total plant B.O.D. if used. In all plants where soap is used for washing, therefore, it is expected to be a major B.O.D. producer. If used in preliminary soaping out before dyeing, or as a penetrant aid in

dyeing, its contribution will be increased.

A completely unexpected conclusion from the inventory survey was the high consumption and B.O.D. contribution of acetic acid. This compound contributed 9 per cent of the total plant B.O.D.

In addition to these major B.O.D. sources, softener cream (sulfonated tallow oil) contributed 5 per cent of the total B.O.D., kierpine extra (sulfonated tall and pine oil) contributed 2 per cent, and Finish T.S. contributed 2 per cent.

Sodium hydrosulfite and other reducing compounds would have contributed 4 per cent of the total B.O.D. if unoxidized. Most of these reducing compounds are oxidized in process, however, and only a small portion of their potential B.O.D. is exerted.

The ten compounds mentioned thus far produced 74 per cent of the total B.O.D. load. In addition to this amount, compounds extracted from the fiber during scouring produced 20 per cent more. The remaining 6 per cent was incorporated in approximately 60 other compounds used by the plant.

The cause for the decided alkalinity of cotton finishing wastes is readily revealed in the extremely high caustic consumption of 118 lb. per 1,000 lb. of cloth. In addition, the highly alkaline soda ash, ammonia, potassium carbonate, sodium phosphates, sodium perborate, sodium silicate, and soap increase this to approximately 200 lb. In contrast, only 45 lb. of acids are used to process each 1,000 lb. of cloth.

A complete inventory and B.O.D. survey of any mill, regardless of size, may be readily finished by one man in 2½ days. Because of the additional information and insight it provides on the characteristics and constituents of the waste, it should be used whenever any mill is being surveyed. Results obtained through it may be used to check and rationalize the results obtained through the analytical survey. With it one may be able to deduce the actual compounds causing the B.O.D. in the particular waste discharges which are analyzed in the routine analytical survey of the individual mill wastes.

Mill Waste Survey

Part of the most significant results from the analytical survey of these individual mill wastes are recorded in Table II. These revealed that the major B.O.D. discharges from the mill were contained in the de-sizing and the scouring wastes.

De-Sizing

De-sizing wastes produced 35 per cent of the total plant B.O.D. The primary source of this B.O.D. is the slashing starch used in originally siz-

TABLE II.—Major B.O.D. Discharges from a Cotton Finishing Mill

Department and Process	B.O.D. (lb./1,000 lb. goods)	B.O.D. Percentage of Total
De-sizing:		
De-sizing	53	35
Scouring:		
Pressure kier, first scour	53	16
Pressure kier, second scour	8	1
Continuous scour	42	15
Bleaching:		
Hypochlorite bleach	8	3
Peroxide bleach	3	1
Mercerizing:		
Mercerizing	6	1
Dyeing:		
Sulfur, jig	30.8	0.2
Direct, jig	0.5	0.1
Naphthol, jig	14.1	0.1
Vat dye, continuous, dichromate oxidation	18.6	0.5
Vat dye, continuous, perborate oxidation	17.5	0.5
Vat dye, jig	31.5	4.6
All processes	—	6.0
Printing:		
Color shop wastes	12	7
Wash-after-printing, with soap	17–30	17–30
Wash-after-printing, with detergent	7	7

ing the fiber to aid in weaving. Most of this starch is actually discharged as glucose, a hydrolysis product produced through the action of hydrolytic enzymes.

Scouring

Scouring wastes accounted for 32 per cent of the total plant B.O.D. Calculations indicated that the process chemicals used in the scouring liquor make-up produced only 20 per cent of this B.O.D. Consequently, the remaining 80 per cent must have been extracted from the cotton fiber. Trade literature indicates that waxes and pectins are extracted during scouring (2) and these are the probable sources of B.O.D. in this waste. These sources produce approximately 40 lb. of B.O.D. per 1,000 lb. of cloth and account for 20 to 30 per cent of the total plant B.O.D. Little or no subsequent pollution is expected to be caused by the scoured cotton fiber unless a dissolving reaction occurs, since it is practically pure cellulose and insoluble in water.

Process chemical sources, consequently, produce 70 to 80 per cent of the total plant B.O.D. Pollution from cotton mills is thus seen to be caused mainly by the process chemicals used and not by the inherent B.O.D. extracted from the fiber.

It is important to note that de-sizing and scouring account for 67 per cent of the total plant B.O.D. In any plan for pollution reduction these processes, therefore, must be given primary consideration. When minimum pollution reduction is necessary, segregation and treatment of these two wastes alone might be considered.

Dyeing and Printing

Dyeing processes (used on only 28 per cent of the cloth) produced 6 per cent of the total B.O.D. If all the cloth had been dyed, 20 to 25 per cent of the total B.O.D. would have been produced. The main sources of B.O.D. in this waste are the dyestuffs, reducing agents (sulfide, sulfite, hydrosulfite, nitrite, glucose, etc.), acetic acid, and soap.

Wastes contributed by printing are discharged from the color shop, where printing pastes are made, and from the wash-after-printing machines. Color shop wastes produced 7 per cent of the total plant B.O.D. The starch, gums, and oils used as thickening agents in the printing paste are the main sources of B.O.D. in this waste.

In the course of this survey, as indicated previously, the mill converted to the use of a synthetic detergent (0 per cent B.O.D.) in place of soap (55 per cent B.O.D.) in the wash-after-printing machine. The B.O.D. of the wash waters from this machine showed a marked drop and calculations indicated a 90 per cent reduction was obtained.

With soap, the wash-after-printing machine produced 20 to 30 per cent of the total plant B.O.D., mainly because the B.O.D. incorporated in the soap molecule was superimposed on the print paste being washed off the cloth. With detergent, only 7 per cent of the total plant B.O.D. was produced. This change reduced the total pollution by the mill approximately 20 per cent and indicated an excellent method for pollution reduction.

The main sources of B.O.D. in wash-after-printing wastes are soap when used, and the starch, gums, and oils from the printing paste.

Bleaching and Mercerizing

Bleaching wastes accounted for 4 per cent of the total B.O.D., both the hypochlorite and the peroxide processes being used in this plant. The B.O.D. source in this waste is not readily ascertainable, although it is believed that the coloring matter in the fiber is rendered soluble on oxidation. Sodium bisulfite, when used, will contribute to the B.O.D.

Mercerizing wastes produced 1 per cent of the total plant B.O.D. The

B.O.D. source is probably a soluble cellulose compound dissolved by the high caustic concentrations (10 to 30 per cent).

The de-sizing, scouring, bleaching, mercerizing, dyeing, and printing wastes so far mentioned thus accounted for 92 per cent of the total plant B.O.D. The remaining 8 per cent was produced in many small discharges from many other processes in the mill. These include softening after printing, levelling off, rust removal, washing after resin impregnation, and causticizing.

Typical Effluent

From the combined surveys one may draw conclusions concerning the general characteristics of cotton finishing wastes. The results indicate that a typical equalized effluent will be a dilute solution of glucose, dextrins, starch, natural cotton compounds (waxes, pectins, etc.), acetic acid, soap, and detergent, mixed with sodium hydroxide, carbonate, sulfate, silicate, and chloride. It will be alkaline (pH 9 to 11) and be slightly tinged with color. The analysis of the equalized composite is expected to be 1,000 to 2,500 p.p.m. total solids, 200 to 600 p.p.m. B.O.D., and 300 to 900 p.p.m. total alkalinity. It will contain 1 to 3 p.p.m. total chromium and probably 1 to 3 p.p.m. sodium sulfite.

Of the B.O.D. present in the waste, 70 to 80 per cent is contributed by process chemical compounds, and 20 to 30 per cent is contributed by natural cotton compounds extracted during scouring. The major process chemical source of B.O.D. is starch. Its contribution is expected to be at least 30 per cent in all mills and may be as high as 60 per cent in mills which print most of their cloth. Most of the starch will have been hydrolyzed to glucose or dextrins. Soap, if used, may contribute as high as 35 per cent of the total B.O.D. Acetic acid is expected to contribute 10 to 15 per cent of the total B.O.D. Assistants used in dyeing may contribute 5 to 20 per cent.

Pollution Reduction Possibilities

Pollution reduction possibilities were indicated in several areas at this mill. The most important one was the 15 to 35 per cent reduction obtainable by substituting a low-B.O.D. detergent for soap. This apparent reduction, however, must be viewed in the light of the B.O.D. discussion following.

A further reduction of 5 to 15 per cent is obtainable if sulfuric acid or some low-B.O.D. acidic compound is substituted for acetic acid. This can be readily done in most processes where acetic acid is now used, since sulfuric acid was used previously. Textile men, however, feared the tendering effect of unremoved sulfuric acid in poorly washed cloth and converted to the volatile acetic acid. Careful washing should remove this difficulty. In wool dyeing, changing from acetic acid to ammonium sulfate has reduced the B.O.D. of the waste dye liquors approximately 70 to 80 per cent.

In final analysis, however, the major need for pollution reduction in the cotton industry is a low-B.O.D. substitute for starch, since this compound produces 30 to 60 per cent of the B.O.D. in cotton finishing wastes. Hydroxyethylcellulose (3 per cent B.O.D.), carboxymethylcellulose (3 per cent B.O.D.), and other cellulose ethers can be used for sizing and thickening and may prove suitable. Price appears to be the major deterrent at the present time.

If such a starch substitute becomes economical, substitution of low-B.O.D. chemicals for high-B.O.D. starch, soap, and acetic acid can produce reductions of 50 to 75 per cent in the total plant B.O.D. This can be obtained merely by substituting one process chemical for another, without building any expensive treatment plant or hiring additional labor.

In addition to process chemical substitution, further pollution reduction may be obtained by use of the less polluting continuous scouring and dyeing methods, by reclamation of caustic, and by use of countercurrent series rinsing.

Theoretical B.O.D. Aspects

The question of the B.O.D. of process chemicals is an intriguing and important one and must be thoroughly investigated. Why the bacteria readily oxidize soap in the standard B.O.D. test and do not attack the detergent molecule is not at present understandable, since portions of their molecules are quite similar. On the basis of their hydrocarbon content, also, the theoretical B.O.D.'s of these compounds are approximately in the same range. More important still, no information is available as to whether or not a bacterial flora will develop in the river to oxidize this detergent. If such a development occurs, the apparent reduction indicated by the B.O.D. test will be false.

Some theoretical B.O.D.'s of common substances are listed in Table III. These were calculated by assuming oxidation to carbon dioxide and water. It will be noted that hydrogen, because of its low atomic weight, has an extremely high oxygen demand. Its incorporation in any molecule may, therefore, possibly increase the oxygen demand. Incorporation of oxygen, on the other hand, will decrease the B.O.D. Many pollution problems would be nicely solved if the process chemical had enough oxygen in the molecule to satisfy its own oxygen demand. This does not appear feasible, however, since the molecule would have to have the empirical formula CH_2O_3. Nevertheless, use of increased oxygen through ketone and ether linkages is possible, and lower B.O.D.'s should result. Reduction by this means is limited, however, since the hydrocarbon portion of the molecule has such a high B.O.D.

TABLE III.—Theoretical B.O.D. of Various Substances

Substance	Formula	Theoretical B.O.D. (%)
Hydrogen	H	800
Carbon	C	267
Nitrogen (→NO_3)	N	343
Methane	CH_4	400
Acetic acid	CH_3COOH	107
Tallow soap	$C_{17}H_{35}COONa$	272
Alkyl aryl detergent	$C_{12}H_{25}\cdot C_6H_5\cdot SO_3Na$	235[1]
Triethanolamine	$(HOCH_2CH_2)_3N$	161[1]
1,4 dioxane	$(CH_2CH_2O)_2$	182[1]
Allyl alcohol	$CH_2{=}CHCH_2OH$	220[1]
Diethylene glycol	$CH_2OHCH_2CH_2OCH_2CH_2OH$	173[1]
Ether	$C_2H_5OC_2H_5$	260
Glucose	$C_6H_{12}O_6$	107
Urea (→H_2O+NH_3)	NH_2CONH_2	0

[1] Low or negligible B.O.D. when analyzed by the standard 5-day B.O.D. test, presumably because of the chemical groupings in the molecule.

More hope is available through the use of functional groupings as blocking agents to prevent or minimize oxidation. Such an effect has been reported by Lamb and Jenkins (3) and by Mills and Stack (4) in work on synthetic organic chemicals and has also been noted, as previously shown, with many synthetic detergents. These authors concluded that many organic materials are relatively stable to aerobic biological oxidation, even though they are not toxic. Whether or not oxidation occurs is dependent on chain structure, molecular size, and the functional groups present. It was found, for example, that polyethylene glycols and their diethoxy derivatives are not readily oxidized. Monoethoxy derivatives are oxidizable and greater oxidation is observed for shorter chain materials. The acetate derivatives of the lower molecular weight polyethylene glycols, on the other hand, were oxidized to a much greater degree.

It was also noted that biological oxidation of aliphatic ketones is dependent on the molecular size. In addition, atoms other than carbon atoms in the chain tend to interfere with oxidation. This was particularly noted with secondary and tertiary amines, ethers, and compounds such as dioxane and mor-

pholine. Polymerization of organic molecules, presumably because of increased molecular size, also interfered with oxidation. These authors also pointed out that 5-day B.O.D. values on synthetic chemicals were frequently low, but 10-day (or longer) B.O.D.'s were much higher in many instances.

A thorough review of this subject may make available to the organic chemists who synthesize the process chemicals knowledge on groupings which will decrease or prevent biochemical oxidation. It is conceivable that the chemist may then tailor-make an organic chemical for processing which will not be readily oxidized or may even modify high B.O.D. molecules, such as soap and starch, to lower their B.O.D.

Incorporation of polypeptide groupings should be investigated because this type of grouping uses the water of hydrolysis as its oxygen source, producing carbon dioxide and ammonia.

$$-\mathrm{CONH}- + \mathrm{H_2O} \rightarrow \mathrm{CO_2} + \mathrm{NH_3}.$$

The ultimate B.O.D. is not reduced, since the ammonia will also have to be oxidized. However, ammonia oxidation usually does not take place until a favorable oxygen balance is present in the stream. Water of hydrolysis is a much more abundant source of oxygen if it could be utilized, because 1 gal. of water contains 7.4 lb. of hydrolysis oxygen, but only 0.0001 lb. of dissolved oxygen.

Summary

The results of the surveys reported herein indicate that the chemicals used in the processing of cotton cloth in the surveyed plant produce 70 to 80 per cent of the total B.O.D. found in the plant effluent, whereas the natural waxes, pectins, etc., extracted from the cotton fiber during scouring produce 20 to 30 per cent. A total B.O.D. load equal to 10 to 20 per cent of the weight of the cloth is discharged during the processing and finishing. Starch, soap, and acetic acid are the major B.O.D. producers among the process chemicals, because of their high consumption and inherent high B.O.D. Possibilities of pollution reduction through substitution of low-B.O.D. chemicals for these high-B.O.D. compounds have been pointed out. Calculations indicate that B.O.D. reductions as high as 50 to 75 per cent may be obtained in this manner, without the installation of any treatment plants whatsoever.

Cooperation among process chemical manufacturers, textile engineers, and pollution abatement agencies is strongly urged to investigate thoroughly these possibilities before expenditures are made in the building of treatment plants. Fundamental long-range B.O.D. studies should be undertaken to determine actual B.O.D. of synthetic chemicals and also to determine the functional groups or other factors which will prevent or minimize oxidation of the process chemicals in the receiving stream. A thorough investigation of alternate processes and chemicals should be made to determine which are the least polluting.

The process chemical inventory and B.O.D. survey should prove useful in these investigations because of the relative ease with which it may be done and because of the additional information it provides on the constituents and characteristics of the wastes. With it, one may determine why the B.O.D. is present and whether it may be eliminated by process chemical substitution. In addition, after sufficient data are collected to indicate average consumption on these chemicals, use of excesses may be quickly detected. This type of survey should also prove useful in the investigation of other industries causing pollution of streams.

Acknowledgment

The authors wish to acknowledge with thanks the financial aid and cooperation of the New England Interstate Water Pollution Control Commis-

sion and the Connecticut State Water Commission. Most of the data used in this paper have been taken from a report published by the New England Water Pollution Control Commission (1).

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SEVEN EUROPEAN COUNTRIES SEND REPRESENTATIVES TO OBSERVE U. S. PROGRESS IN POLLUTION CONTROL

The progress United States industry has made in solving air and water pollution problems recently brought representatives from seven European countries to study American pollution research and control methods. Eleven engineers and technicians arrived from Europe in June to make a six-week trip to industrial centers throughout the country under the auspices of the Foreign Operations Administration.

They devoted particular attention to pollution control facilities installed in chemical plants, oil refineries, and pulp and paper mills. Of special interest to the group were sampling and analytical methods, prevention measures and regulations, meteorological methods, and cooperation between weather bureau stations and industry. Their itinerary included visits to many chemical plants, according to the Manufacturing Chemists' Association.

The group included research scientists, engineers, and industrial management representatives from Belgium, Denmark, France, Germany, Netherlands, Portugal, and Britain. The visitation project was under the direction of the Sanitary Engineering Division, U. S. Public Health Service.

INTEGRATED TREATMENT FOR METAL-FINISHING WASTES *

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Among the industries discharging harmful wastes to rivers and other waters, the electroplating trade is an important element. The chemicals employed in the make-up of electroplating solutions are extremely toxic to aquatic life. Another factor contributing to the seriousness of the question is the fact that the electroplating industry is made up of a large number of relatively small plants dispersed everywhere where metal-working industry is established. The economical burden of waste treatment is naturally much heavier for the smaller establishments, both insofar as investments for treatment facilities are concerned and also because it requires the time of the scarce technically skilled help.

Evaluation of the Wastes

The polluting wastes discharged by the typical electroplating plant may be divided in two general categories, concentrated and dilute.

The concentrated wastes are the spent acid pickling solutions, bright dips, passivating solutions, alkali cleaners, stripping solutions, etc. Generally these are process solutions that have lost their usefulness due to a high build-up in metallic salts, organic materials such as oils, or broken down and expended chemical compounds. The regeneration of these process solutions may be economically unjustified.

The dilute wastes are the diverse rinse waste effluents coming from the electroplating process. Some of the process solutions employed contain such highly toxic compounds that even trace quantities carried by the rinse waters have to be considered toxic (1)(2).

The evaluation of a particular waste treatment problem will depend to a great extent on the local conditions. If it is only the harmful effect of the wastes on the sewers and on the facilities of the local sewage works which has to be avoided, possibly only the concentrated wastes will have to be treated. On the other hand, if the receiver of the waste effluent is a stream, both the concentrated and dilute wastes will require treatment.

The treatment of the concentrated wastes is a relatively simple procedure. The subject is thoroughly discussed in the literature (3)(4)(5). The dumping of process solutions occurs only after reasonably long periods of use. The total quantities are not too large; some of the wasted solutions may be used to effect chemical treatment on others and to help neutralize each other. The chemical reactions involved are well within the scope of the ability of the average plater and even the time required for chemical analysis may be available, as a reasonably sized holding tank will allow a treatment frequency of only once or twice weekly.

The real problem in connection with electroplating waste treatment is the treatment of the dilute wastes. In this case comparatively large quantities of waste are involved because profuse rinsing is a prerequisite of sound plating. Some of the effects of insufficient rinsing could be porosity of the metallic

* Presented at 25th Annual Conference, Pennsylvania Sewage and Industrial Wastes Assn.; State College, Pa.; Aug. 26–28, 1953.

or non-metallic deposits, lack of adhesion, blistering of the deposit, spotting, tarnishing, cloudy films, etc. In addition, continuous dragin of foreign chemical compounds would soon pollute the processing solution next in the line.

The segregation and collection of the dilute waste in holding tanks for treatment is the usual method of treating these wastes (6)(7)(8), although some treatment plants have been built on a continuous treatment basis (9)(10). In any event, the physical treatment plant usually is far more expensive than the productive plating equipment employed in the respective plant, the chemical control is quite involved, and the operating labor expenses are considerable. It is considered economically unsound to operate a waste treatment plant of this type in a competitive market.

Integrated Waste Treatment System

Analysis of the problem as stated in connection with the treatment of the dilute plating wastes might lead to the following conclusions:

1. The pollution problem is due to the discharge of large quantities of rinse waters contaminated by a relatively low concentration of toxic chemical compounds.

2. This waste is not due to some chemical by-product which is a necessary result of the metal-finishing process; rather, it is caused by the requirement of repeated washing during the processing cycle.

From these considerations it follows that if the toxic compounds are eliminated before they are washed off the requirements for profuse rinsing can be met without causing pollution. It is necessary, then, to integrate the waste elimination steps into the processing sequence and to establish the treatment as an organic part of the whole process.

The objectionable chemical compounds may be removed from the work in process before they could reach the sewer by either recirculating the rinse waters through ion exchangers or by chemical treatment preceeding the rinsing steps (11)(12). The scope of this paper is restricted to the integrated waste treatment system based on chemical treatment methods (13).

The general concept of this treatment method may be described as chemical treatment of the objectionable toxic compounds and their removal from the work in process preceding the rinsing with running water.

The chemical treatment solution is kept in a closed system and as a rule is not wasted, but may be discharged after prolonged use. The treatment wash station is an integral part of the finishing line and is connected to a larger treatment solution reservoir. The treatment solution is constantly recirculated, the chemicals consumed in the treatment process being replenished and the precipitated salts removed through settling or filtration. The treatment solution usually contains an excess of the chemicals used for the treatment. This feature avoids the necessity of close control, maintains a more even level of available chemicals regardless of fluctuations in the dragin rate, and in some cases accelerates the anticipated chemical reactions. Since the treatment solution is not expendable, the higher concentration of reagents maintained does not imply wasteful consumption.

The choice of the chemical reaction to be adopted for this type of treatment has to be such that it suits the finishing cycle while fulfilling the objective of toxic waste elimination.

The requirements for a satisfactory treatment solution may be enumerated as follows:

1. It should not tarnish, discolor, or stain the work.

2. It should not harm the functional qualities of the finish (such as corrosion resistance, activity for receiving

subsequent electrodeposits, paintability and paint adhesion, etc.)

3. It should give an instantaneous reaction with the toxic compounds, since the chances for harmful dragout into the running water rinse will depend on the concentration level in the treatment solution.

4. It should lead to a precipitate or gaseous breakdown product to eliminate undue chemical build-up and the need for frequent dumping.

Dependent on the particular treatment to be used, and also to some extent on the receiver of the final effluent, the treatment system may consist of one or two steps with as many different treatment solutions. As an example, there are high- and low-pH cycles, reduction and subsequent precipitation steps, etc.

Evaluation of Method

The advantages of the integrated waste treatment system are numerous and probably decisive for the electroplating trade, as follows:

1. The capital outlay for treatment equipment is but a small fraction of the productive equipment cost.

2. The waste treatment is integrated into the finishing line, thus no separate treatment plant is required.

3. The floor space occupied is small and may be further minimized by occupying space overhead or the below floor level.

4. Some reduction in chemical consumption is achieved, especially when in a conventional batch plant large quantities of wastes have to be subjected to low pH treatment and subsequent neutralization.

5. The need for close chemical control is eliminated due to the wide limits allowed when working with a constant excess of treatment chemicals.

6. No separate personnel is required for the operation of the treatment system. Simple test methods approximating the concentrations of chemicals are sufficient and allow the integration of the waste treatment plant into the regular duties of the supervisory and operating labor usually employed.

7. Reduced quantities of rinsing water may be employed due to the better rinsability of the work after treatment and the reduction in contaminants.

8. The rinse waters are free of high concentration of dissolved and suspended solids; the color and clarity are excellent in comparison with the effluent from a conventional treatment plant.

9. The effluent is far more free of toxic compounds than is the case with the average conventional treatment plant. The reason for this is simple: it is easier to work with an excess of treatment chemicals in a closed recirculated system, especially when it involves the precipitation of trace quantities of heavy metal complexes.

Examples of Integrated Waste Treatment

After Cyanide Plating Solution

The toxic compounds to be eliminated after a cyanide-type plating solution are the cyanide radical and the heavy metal ions, such as copper, zinc, and cadmium. The oxidation of the cyanide complexes through chlorination is one of the simplest, cheapest, and fastest chemical treatment methods and may be employed advantageously in the integrated system. A free chlorine excess of 30 to 80 p.p.m. is used at a pH of 9 to 10.5. Chlorine gas or a hypochlorite solution are equally satisfactory as sources of free chlorine. The underlying chemical reaction has been thoroughly explored (14)(15) and may be assumed to take place in two steps.

The first step—

$$NaCN + 2NaOH + Cl_2 \rightarrow NaCNO + 2NaCl + H_2O$$

—is a very rapid reaction converting the cyanides into cyanates, compounds

of considerably lesser toxicity. With further additions of free chlorine the second reaction proceeds at a somewhat slower rate. At the stated pH, with the excess chlorine stipulated, and at room temperature, in about 2 to 4 hr. the cyanates are broken down into nitrogen and carbon dioxide gas according to the assumed formula:

$$2NaCNO + 4NaOH + 3Cl_2 \rightarrow 2CO_2 + 6NaCl + N_2 + 2H_2O.$$

The relatively high chlorine excess accelerates the breakdown of the cyanates and allows the quantitative precipitation of the toxic heavy metal salts. In the event that the treatment follows copperplating from a Rochelle salt solution, sufficient quantities of calcium chloride or lime must be added to the treatment solution to effect the complete precipitation of the copper (16).

The chlorination treatment solution does not affect the appearance or corrosion resistance of the deposit, neither does it alter the surface activity of a copper deposit insofar as the adhesion of subsequent nickelplating is concerned. A distinct improvement in rinsability is achieved if comparing rinsing after the treatment with washing after plating in an installation without the incorporated treatment step.

Figure 1 shows the flow sheet of a typical integrated treatment line following plating from a cyanide-type electrolyte. The treatment wash solution is constantly recirculated from the treatment solution reservoir. Chlorine gas and caustic soda or a hypochlorite solution is constantly added to the reservoir to replenish the chemicals consumed. The reservoir, besides fulfilling its usual function of maintaining a more even chemical concentration level and acting as a settling tank, also should be of sufficient size to reduce the possible cyanate dragout to just a fraction of 1 p.p.m. in the rinse-water effluent.

Non-toxic salts, such as sodium chloride, sodium carbonate, etc., slowly accumulate in the treatment solution. Every 2 to 4 months, depending on the particular installation, the treatment solution should be discarded and a new treatment solution made up. A holding tank is usually provided for this purpose and also for periodic drawoff for systems using the hypochlorite method of chlorine feed. The use of this holding tank allows leisurely time for analysis, reduction of the excess chlorine, precipitation of possible traces of copper or other heavy metals, adjustment of pH, and slow bleeding off of the clear effluent.

Automatic control instrumentation based on pH control and depending on the redox potential is entirely feasible. It was found that the redox potential maintains steady and dependable values in the free chlorine excess range in question. Absolute values cannot be given because apparently the potential is somewhat influenced by the pH of the treatment solution and by the otherwise irrelevant constituents of the particular plating solution used. The advantages of automatic instrumentation might be questionable in most installations, as a simple test paper check is sufficient to insure that the free chlorine content and pH are at safe levels.

After Copperplating

Even trace quantities of copper salts are toxic to fish and the biological organisms depended upon for the natural purification of streams or employed in sewage treatment plants. Rinse waters from the washing of the work after these processes are serious pollutants if not preceded by rinsing in a proper treatment wash solution. Copper is quantitatively precipitated in an acidic solution of sodium or potassium ferrocyanide. The formula of the chemical reaction may be given as

$$Na_4FeCN_6 + 2Cu^{--} \rightarrow Cu_2FeCN_6 + 4Na^{-}.$$

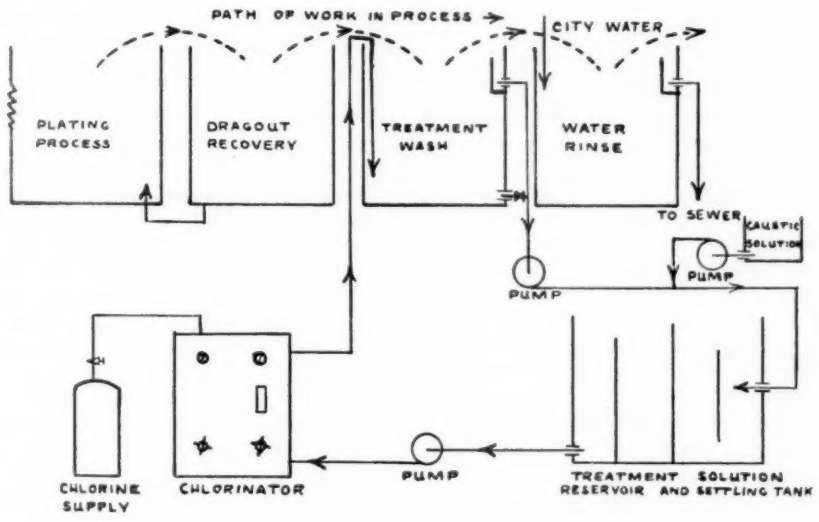

FIGURE 1.—Flow sheet of typical integrated treatment line following plating from a cyanide electrolyte.

The alkali metal ferrocyanide may be considered a nontoxic compound. With constant additions, an excess of 200 to 400 p.p.m. is maintained in the treatment solution; the possible dragout rate is small and will be consumed in the precipitation of iron salts inevitably present in a plating room effluent.

After Chromium Solutions

For treatment after plating with chromium, chromic acid anodizing, dichromate-type passivating dips, etc., a two-step process is usually employed. The first treatment insures the reduction of the hexavalent chromium to the trivalent state; the second treatment serves for the precipitation of the chromic salts.

Sulfur dioxide gas generally is used for the reduction phase of the treatment. There are a number of important considerations making sulfur dioxide the preferred reducing agent in this reaction, as follows:

1. Ease of handling, adjusting the rate of flow, etc.

2. The greater driving force of this reaction allows a wide pH range (from acidic to slightly alkaline) for instantaneous reduction to take place, considering the usual excess of reducing agent in solution (17).

3. The sulfurous acid formed as the gas is absorbed in the solution regulates the pH effectively, eliminating the need for separate acid additions.

4. The basic chromic sulfate formed will require smaller quantities of alkali for the subsequent precipitation (18).

The second treatment step used for the elimination of chromium waste consists of a slightly alkaline wash solution containing traces of reducing agent, such as sodium hydrosulphite ($Na_2S_2O_4$), to maintain a reducing potential and eliminate the possible traces of hexavalent chromium not reached in the first treatment. A sodium carbonate solution at pH 6 to 8 may be employed.

The probably chemical reduction of the hexavalent chromium with SO_2 gas

is as follows:

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$2H_2CrO_4 + 3H_2SO_3 \rightleftarrows Cr_2(SO_4)_3 + 5H_2O$$

$$Na_2Cr_2O_7 \cdot 2H_2O + 3SO_2 \rightleftarrows Cr_2(OH)_2(SO_4)_2 + Na_2SO_4 + H_2O.$$

It will depend on the particular process being used as to the pH level at which the reduction reaction should take place. Although a pH of 2 to 3 is harmless for a treatment after chromium plating, a pH near neutral is required after chromic acid anodizing or dichromate passivation of brass, zinc, cadmium, etc.

Figure 2 shows that the speed of the reaction depends on the pH and excess reducer available, whereas Figure 3 shows the accelerating effects of the increase in temperature. The hydrosulfite ion has an even greater reducing potential for hexavalent chromium compounds and it may be assumed to accomplish instantaneous reduction at an alkaline pH with only a 10 to 20 per cent excess over the stoichiometric equivalent.

The pH of this treatment solution can be raised by alkali additions, whereas the lowering of the pH may be accomplished by increasing the excess SO_2 content, this increasing the sulfurous acid content of the solution. Depending on the pH of the reduction the chromic salts will be hydrated to a different extent. Following the practice of the tanning industry, distinction may be made between chromic salts of different basicity, based on the hydroxyl content. The effect of the pH on the reduction reaction may be expressed in approximate values, as shown in Table I.

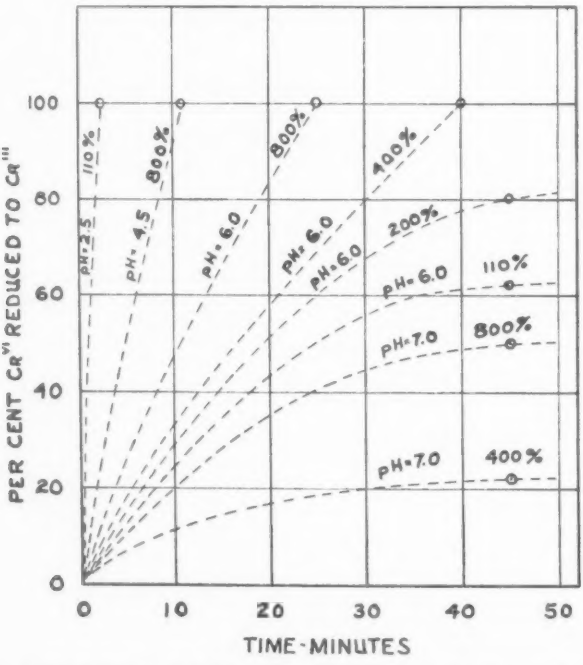

FIGURE 2.—Rate of reduction of hexavalent chromium to the chromic ion, employing SO_2 as a reducer at 22° C. Sample contained 400 p.p.m. CrO_3.

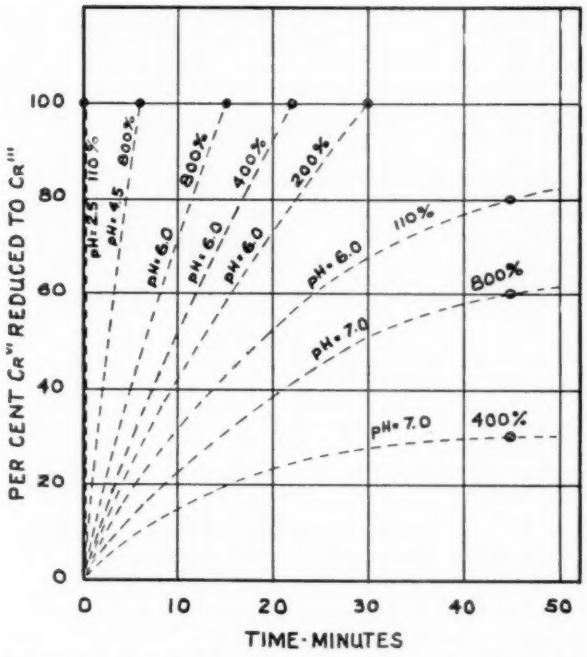

FIGURE 3.—Rate of reduction of hexavalent chromium to the chromic ion, employing SO_2 as a reducer at 50° C. Sample contained 400 p.p.m. CrO_3.

The precipitation of the chromic salts is the aim of the second treatment step, the quantity of alkali required for this reaction depending on the basicity of the chromic compound.

The reaction may be assumed to be as follows:

$$Cr_2(SO_4)_3 + 6NaOH \rightarrow 2Cr(OH)_3 + 3Na_2SO_4.$$

The flow diagram (Figure 4) explains schematically the complete treatment layout. The first treatment wash follows the chromium plating, possibly after a drain station which serves to reduce the chemical dragout. The second treatment is next in the line and is followed by the usual running water or spray rinse employed in electroplating plants. Each of these treatment wash tanks is connected through a pump with a larger treatment solution reservoir and is constantly recirculated. The purpose of the treatment reservoir here is simply to expand the usually small holding capacity (100 to 200 gal.) of the wash station in the line and thus level off possible large fluctuations in the chemical concentration.

The su'fur dioxide is added through a porous stone or lead pipe diffuser after passing through a pressure regulating valve, a flow meter, a gas dryer, and a vacuum breaker.

The chemical consumption in the second treatment solution is small, as only

TABLE I.—Basicity of Chromic Salts

pH	Compound	Salt Type
<2	$Cr_2(SO_4)_3$	Neutral
2–2.5	$Cr_2(OH)_2(SO_4)_2$	33⅓% basic
3–4	$Cr_4(OH)_6(SO_4)_3$	50% basic
4.5–6	$Cr_2(OH)_4(SO_4)$	66⅔% basic
>6.5	$Cr(OH)_3$	100% basic

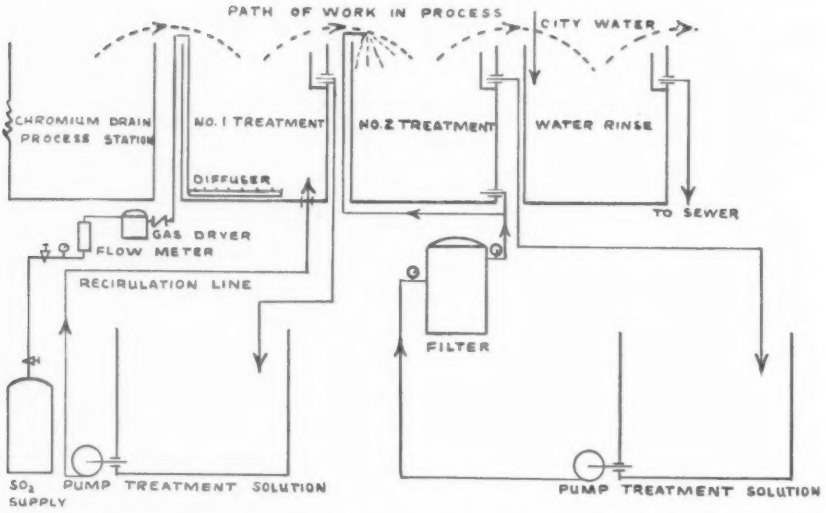

FIGURE 4.—Flow sheet of typical integrated treatment line following a process employing hexavalent chromium compounds.

the chromic salts dragged in from the first treatment step are precipitated here. Manual replenishment of the chemicals once daily is usually sufficient. The insertion of a filter in the recirculating line will constantly remove the small amounts of precipitate formed and perpetuate the usefulness of the second treatment solution.

The first treatment solution is allowed to build up to a concentration of 1 to 2 lb. per gal. chromic acid equivalent in chromic salts and is then pumped to a neutralization tank. Neutralization and precipitation of the chromic salts is effected by the additions of dry lime and the resultant slurry is pumped to a sludge bed for drying. The by-product dry sludge is of commercial value.

The rate of sulfur dioxide flow and pH may be easily controlled automatically by the use of instrumentation based on the redox potential of the solution (19)(20). Manual control is also easy, as it is sufficient to use a spot test to approximate the excess reducer present. Simple pH paper test may take care of the second treatment wash solution.

Benefits Derived

In general, based on practical experience, better rinsing can be achieved, allowing a reduction in the water consumption rate. Cleaner, stain-free finishes may be had, even with shapes notorious for trapped chemicals. The most outstanding difference is noticed after chromium plating; the usual chromic acid drying stains are eliminated, and the plating racks may be maintained with an "as new" appearance. In addition, the chances for contamination of the process solutions are eliminated and the need for better housekeeping teaches better working habits, improves efficiency, and reduces chemical waste.

Summary

A simple treatment of plating waste is made possible for even the smallest plant without incurring great expense. Neither the physical plant nor the operating expenses are of sufficient mag-

nitude to affect the economy of operations. All electroplating plants could be designed in the future to completely eliminate all toxic waste, regardless of any possible lower standards allowed by the local conditions. The cost of waste treatment is low and well worth the benefits derived in the process.

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DESTRUCTION OF OXALIC ACID BY ACTIVATED SLUDGE

By Donald J. Nelson, Leo M. Reading, and C. W. Christenson

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One of the industrial processes at the Los Alamos, N. Mex., atomic energy installation produced a waste containing large quantities of oxalic acid. Because this material is a good complexing agent, it was felt that it would upset chemical treatment when mixed with other wastes treated by coprecipitation. It was desirable, therefore, to devise a method which would economically destroy the oxalic acid. Previous studies (1) indicated that oxalic acid is toxic to activated sludges, but more recent work has also shown that such highly toxic materials as formaldehyde (2) and phenol (3) can be successfully destroyed by biological processes. For these reasons, experimental activated sludges were set up to determine the feasibility of destroying oxalic acid by aerobic oxidation.

Experimental Procedures

Over a period of several months, three experimental sludges were set up, each under varying supplemental feed conditions and with varying feeds of oxalic acid. The experimental sludges were operated by a modified fill and draw method by which the oxalic acid feeds were added slowly over a portion of the total aeration time. The total aeration time was usually 23 hr., allowing a total of 1 hr. for settling, recording data, sampling, addition of special feed supplements, and drawdown. A slow constant feed rate applied the oxalic acid feed solutions to a constantly increasing aeration volume over a period of 7 hr. or more. The aeration volume increased from an initial 7.5 l. to 9 l. during the oxalic acid feed period, and remained at 9 l. for the additional period of aeration. The oxalic acid feed solution was prepared by the addition of a weighed amount of oxalic acid to 1.5 l. of water and partial neutralization with technical grade caustic. The pH of the feed solution was normally kept between 2.5 and 3.5.

Routine analyses were carried out in accordance with "Standard Methods" (4). To determine the oxalic acid content of sludge effluents an aliquot of the effluent was acidified with concentrated sulfuric acid, heated, and titrated with standard potassium permanganate solution (5).

Sludge 1—Oxalic Acid Plus Nitrate and Phosphate Supplement

A sludge which had been used for a study of the utilization of ammonium citrate was used for the initial portion of the experiment to determine the feasibility of the use of activated sludge for the destruction of oxalic acid. The sludge was fed a daily supplemental feed mixture of 500 p.p.m. flour and 500 p.p.m. sugar while the ammonium oxalate feed was increased from 50 (36 p.p.m. as oxalic acid) to 250 p.p.m. (182 p.p.m. as oxalic acid) over a period of two weeks. Microscopic examinations of the sludge during the two-week period of acclimation indicated the zoogleal colony masses were gradually changing. The response was taken as an indication that the sludge was adapting to a new substrate,

since all elements appeared viable and active.

Since acclimation proceeded favorably with ammonium oxalate, 3 l. of the sludge were set up in a 10-l. aerator and feeds of oxalic acid were started. Mineral feed supplements provided daily throughput concentration of 130 p.p.m. NO_3–N and 300 p.p.m., PO_4; the flour and sugar supplement was gradually decreased and finally stopped completely when the oxalic acid feed reached 3,300 p.p.m. Initially, the feed of oxalic acid was equivalent to 1,670 p.p.m. based on the throughput volume (69.3 lb. per 1,000 cu. ft. of aerator volume per day), and this was oxidized to the lower limit of detectability of the permanganate titration.* Feed levels are expressed as parts per million of oxalic acid, although the adjustment of the feed solution pH resulted in an actual feed of sodium oxalate and oxalic acid.

This sludge was continued in operation for 12 weeks at a maximum feed of 3,300 p.p.m. (138.6 lb. per 1,000 cu. ft. of aerator volume per day). Table I is a summary of the data recorded for this sludge. The unusually high ash content of this sludge was probably due to the fact that it had originated from a synthetic feed of citric acid with a high mineral salt supplement and had been maintained on this type of feed for several months.

Although this sludge continued to reduce the oxalic acid concentrations to the lower detectable limit, some of its characteristics were unusual in comparison with a normal activated sludge. Therefore, it was decided to determine the effect of a flour and sugar feed supplement on the ability of the sludge to oxidize the oxalic acid.

Sludge 2—Oxalic Acid Plus Flour and Sugar Supplements

An experimental sludge developed from sewage seed in a 10-l. aerator was fed in the same manner as sludge 1, except that 400 p.p.m. of whole wheat flour and 250 p.p.m. sucrose were added at the beginning of each aeration period. During the period of acclimation, the oxalic acid feed was increased gradually to a maximum of 2,000 p.p.m. (83 lb. per 1,000 cu. ft. of aerator volume per day). This oxalic acid feed level was maintained for 8 weeks and effluent oxalic acid concentrations did not exceed 20 p.p.m. Microscopic examinations of this sludge indicated normal zoogleal masses with new growth as projections and extensions around the periphery of the colony. This type of growth was not altered or limited by the oxalic acid feeds. Table II is a summary of the data for this experimental sludge.

Sludge 3—Oxalic Acid Feed Minimum Flour-Sugar Supplements

As a check on previous findings, another experimental sludge was initiated from sewage seed and maintained on a daily feed of 200 p.p.m. flour, and 150 p.p.m. sugar, plus a mineral supplement of 3 p.p.m. phosphorus (fed as trisodium phosphate), 3 p.p.m. magnesium (fed as magnesium sulfate), and 2 p.p.m. potassium (fed as potassium chloride).

During the acclimation period of 3 weeks, the oxalic acid feed concentration was increased from an initial 25 p.p.m. to a maximum of 2,000 p.p.m. oxalic acid. The sludge was maintained at this maximum oxalic acid feed and observations of sludge characteristics were made. Turbid effluents and poor settling characteristics

* In the case of these sludge effluents, the lower limit of detectability of the permanganate titration was considered to be 20 p.p.m. oxalic acid, since blank titrations determined on both the filtered and unfiltered effluents from sludges on similar feeds, but lacking the oxalic acid feeds, yielded permanganate demands equivalent to 10 to 20 p.p.m. oxalic acid. For this reason, any permanganate titrations that yielded a value equal to or less than 20 p.p.m. should be regarded as indicating no detectable amount of oxalic acid.

TABLE I.—Summary of Data for Sludge 1; 3,333 P.P.M. Oxalic Acid Plus Mineral Supplement

Date		Effluent (p.p.m.)			Mixed Liquor	
		B.O.D.	$H_2C_2O_4$[1]	NO_3-N	S.S. (p.p.m.)	Ash (%)
9/13-12/6	Min.	1	0	70	2,674	52.1
	Max.	20	40	395	4,880	69.9
	Av.	5.07	11	193.2	3,450	64.1
	No. Det.	54	83	53	56	56

[1] See text footnote.

were observed initially but permanganate titrations during the two-week period at maximum oxalic acid feed at no time indicated detectable amounts of oxalic acid in the effluent.

As a further check on the ability of the sludge to oxidize rapidly the oxalic acid feeds, a twice daily feed was attempted. For this procedure the sludge was given its regular feed at approximately 8:00 AM, then given a second feeding of oxalic acid in the late afternoon after an aeration period of 7 to 8 hr. A second feed of flour and sugar was eliminated because it was felt that it would result in an excess of a more rapidly utilized feed and a lengthening of the time for oxalic acid conversion. This second aeration period was about 16 hr.

Examination of the data in Table III shows that permanganate titrations of the effluent after 16-hr. aeration always indicated no residual oxalic acid. The effluent oxalic acid concentrations after the 7-hr. aeration period were erratic, with a maximum of 400 p.p.m. This maximum residual was equivalent to 3.8 g. of oxalic acid, or an approximate residual of 30 per cent.

Anaerobic Digester

Concurrently with the operation of the experimental activated sludges, an attempt was made to adapt a two-stage digester and aerator to oxalic acid feeds (6). This project was abandoned when results showed no significant destruction of the oxalic acid in the anaerobic digester and when detrimental effects on the second-stage aerator were produced by the digester effluent.

Conclusions

Three batch-fed activated sludges, each with a different feed, were able to oxidize oxalic acid feed levels up to 2,000 p.p.m. (83 lb. per 1,000 cu. ft. of aerator volume per 24 hr.). In all

TABLE II.—Summary of Data for Sludge 2; 2,000 P.P.M. Oxalic Acid Plus Flour, Sugar, Mineral Supplement

Date		Effluent (p.p.m.)			Mixed Liquor	
		B.O.D.	$H_2C_2O_4$[1]	NO_3-N	S.S. (p.p.m.)	Ash (%)
10/10-12/6	Min.	4	0	30	2,624	7.4
	Max.	29	40	112	7,440	12.5
	Av.	10.9	20	79.8	4,893	9.4
	No. Det.	30	56	25	37	37

[1] See text footnote.

TABLE III.—Data for Sludge 3[1]

Days After Acclimation	Terminal pH, Mixed Liquor			$H_2C_2O_4$, Effl. (p.p.m.)			Sludge Density Index		Susp. Sol. (p.p.m.)		Ash (%)	
	Single Daily Feed	Twice Daily Feed		Single Daily Feed	Twice Daily Feed		Single Daily Feed	Twice Daily Feed	Single Daily Feed	Twice Daily Feed	Single Daily Feed	Twice Daily Feed
		7-Hr. Aer.	16-Hr. Aer.		7-Hr. Aer.	16-Hr. Aer.						
1	8.6	8.7	8.8	<20	<20	<20	—	—	—	—	—	—
2	8.7	8.8	8.9	<20	<20	<20	—	1.96	—	3,726	—	8.0
3	8.7	8.9	8.9	<20	—	<20	2.20	—	3,530	—	11.2	—
4	8.8	8.8	8.9	<20	—	—	—	2.11	—	4,010	—	8.0
5	8.8	8.9	—	<20	—	—	—	—	—	—	—	—
6	8.6	8.8	8.8	<20	<20	<20	—	2.72	—	4,626	—	7.0
7	8.8	8.7	8.8	<20	210	<20	1.94	—	3,290	—	10.0	—
8	8.8	8.9	8.8	<20	425	<20	—	—	—	—	—	—
9	—	8.8	8.8	<20	50	<20	—	2.77	—	4,700	—	6.0

[1] Feed for 6-l. throughput: 2,000 p.p.m. $H_2C_2O_4$, 200 p.p.m. flour, 150 p.p.m. sugar, 3 p.p.m. Mg, 3 p.p.m. PO_4—P, and 2 p.p.m. K.

cases the effluents contained less than 20 p.p.m. oxalic acid, a removal efficiency approaching 99 per cent.

From laboratory data there are positive indications that acclimation to the oxalate ion by an activated sludge can proceed to a extent which will allow the sludge to receive daily feeds of 2,000 p.p.m. oxalic acid. Under proper conditions and with rigid process controls an activated sludge may produce effluents containing less than 25 p.p.m. oxalic acid when operated on a twice daily feed of 2,000 p.p.m. No continuous process data are available, but if batch process results can be extrapolated, a continuous process activated sludge with precise operation control should be able to produce satisfactory effluents with feeds of 83 to 166 lb. oxalic acid per 1,000 cu. ft. of aerator volume per day.

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DISPOSAL OF ELECTROPLATING WASTES BY ONEIDA, LTD.*

V. Plant Operation

By Paul W. Eichenlaub and James Cox

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The waste treatment plant at Oneida, Ltd., was put into operation during the latter months of 1953. In October, treatment of silver-bearing cyanide waste was begun. In December the first attempts were made at treating the remaining alkali and acid wastes.

Silver Recovery

The start-up of treatment of silver-bearing cyanide waste was simply a matter of diverting this waste from the previous method of treatment—namely, zinc precipitation—to the plant treatment tanks. The method of treatment previously discussed (8) had been piloted so thoroughly that no difficulties were encountered in the precipitation of the silver as the chloride. However, it should be noted that the proposed method of treatment (8) provided for the complete oxidation of cyanide. This involved a pH adjustment, and analysis for both cyanide and cyanate was necessary in order to determine the chlorine dosage. The supernatant from the silver chloride precipitation is decanted to the alkali sump and, thereby, included in the alkali waste. It will be noted subsequently in this discussion that an analysis for cyanate is necessary in the treatment of the alkali waste. Therefore, it was deemed advisable to simplify the treatment for silver recovery to the point of oxidation of cyanide to cyanate only, which eliminated an initial pH adjustment and an analysis for cyanate. Since oxidation of cyanide to cyanate proceeds rapidly at the pH of the collected waste (10.5 to 11.5), no pH adjustment is necessary. The supernatant being decanted to the alkali sump and treated as alkali waste, an analysis for the cyanate from this source is included with the cyanate analysis necessary to the alkali waste treatment.

Preliminary investigation and pilot plant studies had indicated that approximately 99 per cent recovery of silver as the chloride could be expected from this method of treatment. Table X is a graphic example of the value of a well-planned preliminary investigation.

A study of the results in Table X indicates very successful silver recovery, but it will be noted that the oxidation of cyanide is not complete despite the presence of excess chlorine in the supernatant. This cyanide has been found to be in the form of iron cyanide complexes, which resist chlorination. When the supernatant from the silver wastes is blended into the raw alkali wastes, this cyanide is not oxidized. It does not appear in appreciable concentrations in the final plant effluent, however, partly because of the diluting effect of the much larger volume of alkali wastes and partly because the iron cyanide complex is precipitated to some extent, possibly as a copper salt.

After approximately one month's operation of this treatment, enough silver

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

chloride had been collected to proceed with the filtering operation. In the previous discussion (1) no mention was made of any particular type of filter for the removal of silver chloride from the slurry. Instead, it was felt that the final choice of equipment should be based on actual conditions to be met. An 18-in., 8-plate, rubber-lined Sparkler filter with Hastelloy C compression rings and tie rods was borrowed from a department in the manufacturing plant for experimental filtering. Filtration was found to be complicated by the slimy characteristics of the silver chloride sludge.

Investigation showed that the base metals present as hydroxides were the cause of the unfavorable filtering characteristics of the sludge. Laboratory tests showed that filtering characteristics were greatly improved by dissolving these metal hydroxides with acid. It was therefore decided to line the sludge receiving sump with acid-proof brick to make provision for treating sludge with acid. Upon completion of the lining, another filter run was made on a batch of silver chloride slurry acidified to pH 3. This run proved to be much more successful than the first trial. On the basis of this experience a similar filter of larger capacity was obtained. It is anticipated, with a filter of approximately 5-cu. ft. capacity, that the drawoff from the treatment tanks to the sludge conditioning tank and subsequent filtration will be done once a month. The silver content of the chloride thus obtained after drying is of the order of 67 per cent.

Alkali and Acid Wastes

The foregoing discussion covers only a small portion of the total waste to be treated. Proving operations on the treatment of the main wastes were started late in November. During this period the instrumentation and automatic controls were being installed. The value of adequate instrumentation was proved when these initial process runs were made, as continuous treatment could not be carried out because of the many process steps which had to be controlled locally. Even though there were many cases of overflowed sumps and treatment tanks, struggles with proper pH maintenance and sodium hypochlorite additions for cyanide oxidation, etc., enough waste was processed to prove that the treatment scheme was basically sound and that any modification necessary to improved processing could easily be made. Gradually, as instrumentation and automatic controls were put into operation, it became possible to process increasingly larger amounts of the total factory waste. The putting-into-service and calibration of automatic controls was done in stepwise fashion, first by putting controlling instruments

TABLE X.—Typical Results of Operation of the Silver Recovery System for One Month

Batch No.	Raw Waste			Supernatant		
	Total CN^- (p.p.m.)	pH	Silver (p.p.m.)	Silver (p.p.m.)	Total CN^- (p.p.m.)	Excess Cl (p.p.m.)
1	642	10.7	564	8.2	70	34
2	829	10.65	585	4.4	86	149
3	509	11.15	401	2.7	35	—
4	348	10.4	331	6.5	30	14
5	389	10.7	364	2.7	54	77
6	672	10.6	533	5.1	56	51
7	431	10.7	440	0.7	40	116
8	159	10.2	130	0.0	15	173

into operation and then doing the same for indicating and recording instruments.

By the first week of January, 1954, the completion of instrumentation installation was far enough advanced to start the processing of all factory wastes. After a week's operation, some inconsistencies with the planned design became apparent.

Flow Rates

Flow rates of both alkali and acid wastes from the manufacturing plant exceeded the survey measurements by considerable amounts. This was in part due to the addition of several departments engaged in defense work since the waste survey was made, and also to a general laxness on the part of workmen in shutting off rinses when not in use. Although this increase was not too alarming, due to the fact that the wastes plant was designed with a large factor of safety, it was felt that the situation warranted a resurvey and a decrease in water usage wherever possible.

Consequently, a man was appointed to recheck all flowing rinses and decrease the flows to the individual rinses to a point at which a minimum of water was used with no impairment of the quality of work being processed. Upon completion of this survey, controlling orifices were installed in the rinse lines to permanently maintain the desired flow rates. Concurrently, a directive was issued to all foremen in the manufacturing plant informing them that all rinses must be turned off during periods of non-operation. This program resulted in a decrease of approximately 40,000 g.p.d. in the flow received by the waste treatment plant.

Hypochlorite Usage

In the early operation of the plant there was some concern about hypochlorite usage, since it appeared that the actual concentrations of cyanides in the wastes far exceeded all previous estimates. This was found to be a temporary situation caused by a general clean-up in the plant just before an inventory period. However, it was obvious from this experience that the hypochlorite demand during clean-up periods in the future would exceed the capacity of the hypochlorite manufacturing system. Hence, a 3,000-gal. tank was installed for storage of hypochlorite purchased from outside sources for use during periods of unusually high demand.

Cyanide Oxidation

It was pointed out previously (9) that two procedures for carrying out the oxidation of cyanide to carbon dioxide and nitrogen were considered, both involving the use of chlorine or hypochlorite as the oxidizing agent and differing only in the pH used. The chemical reactions involved in either case are:

$$CN^- + Cl_2 \rightarrow CNCl + Cl^-$$
$$CNCl + 2NaOH \rightarrow NaCNO + NaCl$$
$$NaCNO + \tfrac{3}{2}Cl_2 + 2NaOH \rightarrow CO_2 + \tfrac{1}{2}N_2 + 3NaCl + H_2O$$

When these reactions are carried out at a pH value of about 8.5, the first two reactions are substantially complete in a few minutes but the third reaction requires perhaps 2 to 3 hr. to approach completion reasonably closely. The oxidation can be carried out in less time by allowing the first and second reactions to occur at pH 8.5 or above and then adding acid to lower the pH of the reaction mixture to 6.5. At this lower pH value the third reaction is substantially complete in a matter of a few minutes.

It will be noted that the proposed plant procedure (8) called for oxidation of cyanide at pH 8.5, despite the longer time required by this process as compared with the use of a lower pH for cyanate oxidation. This choice was made because other considerations, such as a schedule of operator's duties,

dictated the use of a minimum period of about 6 hr. for the cycle time on the alkali waste treatment tanks. With this much time available it appeared that the use of a single pH for the oxidation would be quite satisfactory and would have the advantage of eliminating one process step, the addition of acid to lower the pH.

In putting the plant into operation it was found after considerable effort that the scheme involving the use of a higher pH (> 8.5) for cyanide oxidation to cyanate and a lower pH (about 6.5) for oxidation of cyanate gave the following important advantages over oxidation at a single pH:

1. The occasional appearance of cyanogen chloride odors in the filter room is avoided. When oxidation at a single pH value was used there occasionally occurred a combination of circumstances which led to a definite odor of cyanogen chloride. This is simply to say that there appears to be no single pH at which all of the reactions given proceed at appropriate rates. It is particularly important that a relatively high pH (> 8.5) be maintained until the second reaction is complete.

2. The chlorine consumption of the wastes is considerably less if the two-step oxidation is used. It is assumed that this is due to the elimination of reactions between chlorine and materials other than cyanide or cyanate, apparently because these reactions became very slow at lower pH values.

It should be borne in mind that very minute concentrations of cyanogen chloride were obvious in this plant because of the indoor location of the sand filters. Checks on the actual concentrations indicated no more than 2 p.p.m. CNCl in the final effluent.

On the basis of these factors and a number of plant runs extending over several weeks, it was decided to use the two-stage oxidation scheme for cyanides. Chlorine dosages have been calculated on the basis of analyses of the wastes for cyanide and cyanate. The chlorine dosage is taken as the theoretical (7.5 lb. of chlorine per pound of cyanide plus 2.5 lb. of chlorine per pound of cyanate). That this scheme is functioning very well is shown by the results in Tables XI and XII.

The change in processing necessitated a provision for pumping acid to the oxidation tanks in order that the pH might be lowered in the step described. Consequently, a Duriron pump of proper size was acquired and a Saran-lined pipe header was installed from which three separate take-offs were made to the three oxidation tanks.

TABLE XI.—Cyanide Oxidation with NaOCl

Tank No.	Date (1954)	Raw Waste			Treated Waste		
		Total CN (p.p.m.)	CNO (p.p.m.)	NaOCl (gal.)	Total CN (p.p.m.)	CNO (p.p.m.)	Excess Cl_2 (p.p.m.)
1	2–15	88.1	4.6	358	2.03	9.2	13.5
2	2–15	8.8	72.0	168	1.69	2.2	5.7
3	2–16	21.1	4.5	92.5	1.17	—	3.8
1	2–16	19.8	2.8	83.8	0.78	—	6.4
2	2–17	25.0	0.0	93.5	0.20	5.5	9.2
3	2–17	21.7	5.6	99.5	0.77	0.4	20.0
1	2–17	16.9	56.3	144	0.68	1.7	10.7
2	2–18	25.2	2.1	104	1.63	—	8.5
3	2–18	18.5	4.4	82.1	0.88	1.4	9.2
1	2–19	19.5	0.0	77.0	0.21	—	3.5
2	2–19	12.1	7.7	63.9	0.52	0.0	11.4

TABLE XII.—Final Effluent Analysis

Date	Total CN^- (p.p.m.)	Cu (p.p.m.)	Ni (p.p.m.)	Zn (p.p.m.)
2- 8-54	0.20	—	—	—
2-11-54	1.67	0.30	0.18	0.02
2-15-54	0.07	0.18	0.09	0.00
2-16-54	0.26	—	—	—
2-17-54	0.09	0.16	1.90	0.19
2-18-54	0.32	0.16	0.55	0.04
2-18-54	0.03	—	—	—
2-19-54	0.09	0.18	1.53	0.23
2-19-54	0.41	—	—	—
2-22-54	0.13	—	—	—

Acid-Alkali Balance

At the time of the preliminary survey, it was realized that a close balance between acid and alkali wastes would be necessary to the processing. Accordingly, spot samples of alkali and acid wastes were taken and pH adjustments were made corresponding to those necessary to the treatment process. These tests indicated a ratio of one part waste acid to four parts of alkali waste (9). The projection of laboratory-scale treatments to large process operations did not prove to be completely accurate. Ordinarily, amounts of waste acid sufficient to balance the alkali waste are available. Periodically, however, batches of alkali waste are collected which are so well buffered that the supply of waste acid is exhausted in overcoming the buffering action. A 3,000-gal. sulfuric acid storage tank and the necessary piping has been installed as a provision for maintaining the waste acid at a sufficient strength.

Floc Formation

The injection of ferric chlorine solution at a point preceding the skimmer was originally intended to accomplish two objectives; namely, adjustment of pH and supplementing the metal content of the combined waste. Experience has shown that pH adjustment must be achieved only by controlling the volume of waste acid added, because the use of ferric chloride for this purpose results in the formation of too great a quantity of sludge for the maintenance of the proper sludge blanket in the thickener.

Construction Materials

A source of real trouble has been the oily nature of the alkali wastes. These wastes pass through a closed pH adjustment tank prior to collection in one of the three cyanide oxidation tanks. At this point, it is necessary to introduce either waste acid or lime slurry to obtain the resultant pH of 9.0. Because of the acid injection at a point upstream from the pH adjustment tank, this tank was equipped with a rubber lining and the agitator which provides for mixing was rubber-covered. The oils so deteriorated the agitator covering that the latter were completely stripped and the coating passed through the system and became lodged in the effluent valves from the oxidation tanks. This necessitated removal of the valves for dislodging of this material. It is hoped that the rubber lining on the tank itself will hold. If it shouldn't, it would be an extremely difficult task to strip the tank completely and remove pieces of coating which may have entered the pumping system.

pH Controls

The pH adjustment of the entering alkali wastes is accomplished by means of a circular-chart pneumatic pH controller, which receives a signal from a pH amplifier. The pH electrode assemblies used in connection with the amplifier are immersed in pH sampling tanks, through which a continuous stream of waste from the effluent side of the pH adjustment tank is flowing. Even though a duplicate set of electrodes is provided so that one set may

be in operation while the other is being cleaned and stored in clean water, maintenance of the electrodes for correct pH measurement is an extremely difficult task. The oils contained in the waste almost immediately coat the electrodes and the measurements become less and less accurate. It has only been possible to maintain the pH measurement of the waste to any degree of accuracy through constant cleaning of the electrode assemblies. For this purpose a cleaning kit has been installed adjacent to the measuring equipment. This kit includes a supply of carbon tetrachloride, used for removing oils; a supply of methanol, for removing carbon tetrachloride from the surfaces of the electrodes, thereby providing a water-wettable surface; and a supply of paper tissues for wiping.

The same situation exists at seven other points of pH measurement or control of the wastes in process, becoming progressively less of a problem as the oils are removed from the waste in subsequent processing operations.

Conclusions

Basically, the processing of wastes ran smoothly according to the proposed treatment procedures (8). The complete success of the entire treatment can be seen by comparing Table XII with Table IV (10). Because of the complexity of the treatment involved and because each waste treatment problem has its own peculiarities and requirements, it was anticipated that problems would arise necessitating changes and modifications in the treatment process and the processing equipment. The design of the plant was so flexible that necessary changes and modifications were and are being made with a minimum of difficulty.

The straight-forward way in which the entire program has been carried out is illustrated by noting that from the time of initial contact with consultants to the completion of the plant to a point where all industrial wastes produced by the Sherrill plant of Oneida Ltd., were being treated, required a period of only two years and nine months.

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CORRECTION

In the paper on "Analysis of a Stream's Capacity for Assimilating Pollution," by M. A. Churchill (THIS JOURNAL, **26**, 7, 887; July, 1954), the drawing shown as Figure 5 (page 899) should be interchanged with the drawing shown as Figure 7 (page 901).

Stream Pollution

CONTROL OF BLUE-GREEN ALGAE BLOOMS WITH 2,3-DICHLORONAPHTHOQUINONE

By George P. Fitzgerald and Folke Skoog

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In an earlier paper (1), results of screening tests on a number of organic chemicals showed that quinones are generally toxic and that 2,3-dichloronaphthoquinone (2,3-CNQ) * is highly and selectively toxic to bloom-producing blue-green algae, including species of *Microcystis, Aphanizomenon, Anabaena,* and *Gloeotrichia.*

The present paper reports results of field experiments involving large-scale applications of 2,3-CNQ to eliminate and prevent recurrence of heavy growths of the bloom-producing blue-green algae. The main experiments were carried out on Spaulding's Pond, a 27-acre pothole lake with an average depth of 10 ft., located near Janesville, Wis. This lake, which receives the drainage from approximately 200 to 300 acres of rich agricultural land and has no outlet, is extremely fertile, and is known to support a continuous, heavy bloom of blue-green algae during the summer months. During 1952 and at the time tests were started in 1953, higher aquatic vegetation was nearly absent. The pH of the water during the course of the summer varied between 9.2 and 9.7. Zooplankton, snails, and fish (largemouth bass) were abundant.

Materials and Methods

The 2,3-dichloronaphthoquinone (2,3-CNQ) was used in the form of a paste containing 50 per cent active ingredient with wetting agent and 50 per cent water. This preparation is miscible with water and, therefore, can be readily applied in various dilute suspensions.

The chemical was applied as a water spray from a motor-driven, 1¼-in., direct displacement water pump operating at a capacity of 35 g.p.m. This pump and a 30-gal. drum, for mixing, were mounted in a 12-ft. motor boat. The chemical was added to the mixing drum through a 10- by 16-in., narrow-snout funnel (aperture about ¼ in.), which provided a fairly constant flow rate of about 50 lb. per hour. Water was circulated through the drum and the suspension (stock mixture) was withdrawn through an outlet pipe near the bottom of the drum. This pipe carried the suspension to the inlet of the pump, where it was mixed with a much larger volume of water drawn in from the lake. A bleeder line from the outlet of the pump was used to maintain a constant volume of 10 gal. in the mixing drum. The rate of circulation through the drum was adjusted by valves in the outlet and bleeder lines. A 1½-in. fire hose with nozzle was used for distributing the spray over a 30- to 40-ft. wide area on the lee side of the boat. The pumping rate was not varied, but an attempt was made to get uniform distribution of the spray by adjusting the speed of the boat in accordance with the depth. However, in local areas with

* Now standardized as "dichlone."

exceptionally high concentrations of algae, the rate of application was increased accordingly. The rates of application varied between 18 and 50 lb. per treatment of the lake, corresponding to concentrations of from 20 to 55 p.p.b. (parts per billion).

For purposes of estimating the growth density of the algae, 20-qt. samples of water were collected from each of two or more fixed stations on the lake. The samples were strained through a fine plankton net and the algae were rinsed into bottles with small volumes of water to a total of 250 ml. On return to the laboratory, the bottles were placed in the refrigerator (10° C.) overnight to allow any debris to separate from the algae. Aliquots (200 ml.) from each bottle were centrifuged and the algae placed in tared weighing bottles, dried in a forced-draft oven at 63° C. for 24 hr., and then weighed. The remaining 50-ml. suspension was preserved with formaldehyde (2 to 4 per cent) for later reference. As sample dry weights of 10 mg. or less per 20 qt., consisting mainly of debris and zooplankton, were obtained from the lake even when the water was clear and practically free from blue-green algae, only values in excess of 10 mg. were considered as indicative of algal bloom conditions.

As a further, indirect, check on the effectiveness of the treatment, samples were collected from Lake Waubesa, another fertile lake in the area, which also tends to support continuous blooms of blue-green algae.

Results

Treatment of Spaulding's Pond was begun on July 10, 1953, when the first blue-green bloom (*Microcystis*) was appearing, and was repeated at intervals until October 2. The exact dates and concentrations of chemical are indicated in Figure 1. It may be seen that a total of eight treatments with from 20 to 53 p.p.b. of 2,3–CNQ were administered in the period from July 10 to July 28. The first two treatments effectively eliminated the existing population of *Microcystis*, but *Aphanizomenon* replaced it. Successive applications with higher concentrations of the chemical were therefore made at close intervals of time to get more effective killing and to stop the development of any recurring growth in its early stages. As a consequence of these treatments, the lake was kept practically clear from July 20 until about August 5, including one week following the last application. The lasting effect may well have been due to the dense growth of the green alga, waternet (*Hydrodictyon* sp.), and the appearance of various aquatic plants, such as bushy pondweed (*Najas* sp.) and waterweed (*Anacharis* sp.). The growth of the latter plants increased rapidly in this period and they undoubtedly removed much of the available nutrients.

A second bloom of *Microcystis* appeared in the second week of August, reaching a concentration of about 70 mg. per 20 qt., at which time the lake was sprayed. The following day the *Microcystis* had clumped at the surface and was rapidly decomposing to the extent that the north (windward) end of the lake was colored a light blue by the released pigment, phycocyanin. Following this single treatment the water was clear and practically free from blue-green algae until the early part of September. During this period green algae and aquatic plants were abundant.

The second week of September there was a rapid growth of *Aphanizomenon*. Masses of the algae became attached to and covered the aquatic plants so completely that the latter were killed, apparently from this cause. A treatment on September 18 caused clumping of the *Aphanizomenon* and killed a large portion of the population. However, since the beds of aquatic plants were dead at this time, the nutrient supply must have been very high, and this

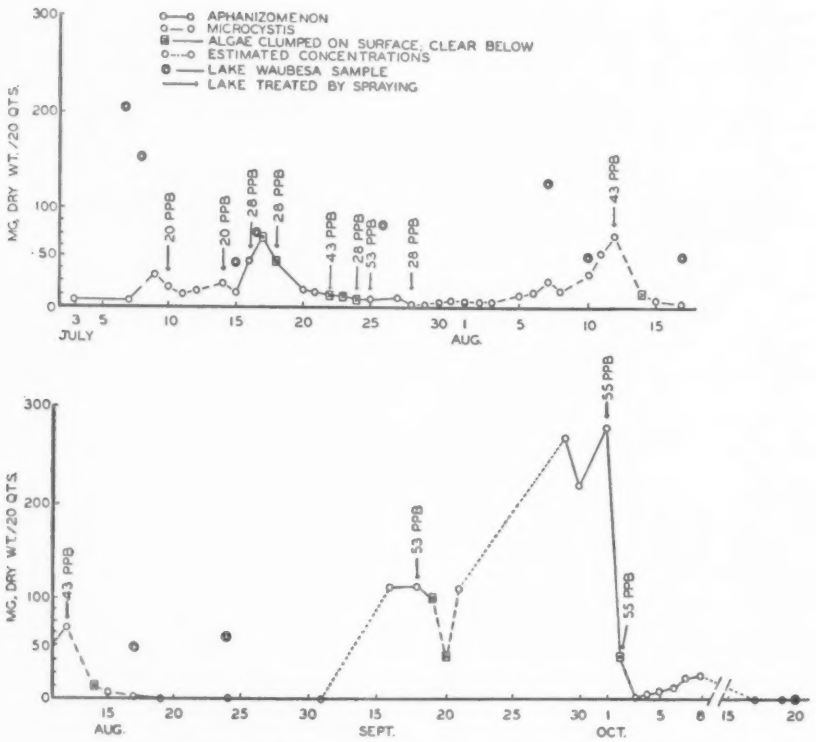

FIGURE 1.—Effect of 2,3-dichloronaphthoquinone treatments on blue-green algae in Spaulding's Pond (1953).

may account for the rapid recovery of *Aphanizomenon* and some additional growth of *Microcystis*. The total population of the two species reached exceedingly high values (about 270 mg./dry weight per 20 qt.) at the end of September. Two successive treatments with 55 p.p.b. 2,3–CNQ, on October 1 and 2, clumped and eliminated this algal population and the lake remained fairly clear throughout the month of October.

During the months of July and August, samples were taken at intervals from one station on Lake Waubesa, and the densities of growth obtained in this lake are indicated by an encircled triangle in Figure 1. The fact that a bloom was maintained continuously in this lake indicates that conditions were favorable for algal growth during these months when the blooms on Spaulding's Pond were prevented by the chemical treatments. Although no samples were collected from Lake Waubesa during the latter part of the summer, bloom conditions were observed to continue and were recorded until October 15.

Discussion

Although it is difficult to obtain quantitative data on the effects of large-scale applications of algaecides, partly because of the variability in growth and distribution of the organisms, and partly because of the lack of direct controls, the effects of treatments of Spaulding's Pond were strikingly evident from visual inspection

and it is felt that 2,3–CNQ, when applied in sufficient concentration (30 to 50 p.p.b.) is effective in eliminating even very heavy blooms of blue-green algae. The treatments had no apparent adverse effects on the fish and general biotic conditions in the lake. Observations carried out by the Wisconsin Conservation Department in conjunction with these experiments have shown that the population of fish and zooplankton was abundant and remained unaffected by the treatments.

Prior to the large-scale treatment of Spaulding's Pond, various tests had been carried out to determine possible harmful effects of treatments with 2,3–CNQ on aquatic animals and plants. Several small-scale applications were made in experimental tanks and isolated lagoons on Lake Waubesa. No harmful effects on fish were observed from concentrations which effectively killed the blue-green algae. Furthermore, continuous applications of the chemical to maintain concentrations in the water of from 20 to 40 p.p.b. over a period of several weeks were carried out on a lagoon connecting with Lake Mendota and with the Yahara River at Tenney Park, and continuous applications for several days at a time were made to the Yahara River at the locks between Lakes Waubesa and Kegonsa. At Tenney Park, a suspension of the chemical was thoroughly mixed with the inflow water, which enters at a rapid and fairly constant rate through an inlet tube from Lake Mendota and then passes slowly through the lagoon. This arrangement, therefore, was very favorable for observations on the effect of the chemical. No indications of damage to the vegetative or mixed fish population were obtained. In the continuous application of 2,3–CNQ to the Yahara River, similarly, no damaging effects were observed. In this case the chemical treatment caused a definite reduction (50 per cent or more) in the heavy algal population carried by the river from Lake Waubesa, as was established by sampling the water before, during, and after the treatments at six successive stations over a distance of 2.5 mi. from the point of application. A number of short-term experiments have also been carried out in aquaria, partly in cooperation with the Wisconsin Conservation Department, which indicated that the chemical in the concentrations necessary to kill the blue-green algae is non-toxic to fish, snails, and to higher aquatic plants.

In cases where the chemical may be used to kill very heavy blooms it is not excluded that temporary toxic conditions may arise secondarily in connection with the rapid decomposition of large masses of algae subsequent to the treatment. Such conditions are known to occur, also, in the absence of chemical treatment when algae are aggregated by wind and wave action and undergo rapid decomposition.

The present results indicate that the single treatment in itself is effective in preventing growth of algae only for a period of a few days. However, repression of the growth of the blue-green algae offers an opportunity for vigorous growth of green algae and for the establishment of higher aquatic plants, which in their turn may retard the development of blue-green blooms. The question of optimal dosage and frequency of treatment will vary with the conditions in each location and can only be worked out in a general way by extensive practical testing. Similarly, the possible effectiveness of partial (shoreline) treatments remains to be investigated. Considering the high potency and selectivity of 2,3–CNQ, together with its effectiveness as demonstrated in this large-scale test, it would appear that the chemical might provide a more efficient and practical means of controlling blooms of blue-green algae than do the methods now in use.

Summary

A large-scale test of the effectiveness of 2,3-dichloronapthoquinone (2,3–CNQ) in controlling excessive growths of blue-green algae has been carried out on Spaulding's Pond, Wis. This 27-acre, highly fertile lake normally supports a continuous bloom of algae during the summer months.

Spray applications of 2,3–CNQ suspensions to give over-all concentrations from 30 to 55 p.p.b. in the lake clumped and effectively killed even heavy growths of the blue-green species. The chemical treatment had no observable harmful effects on green algae, higher aquatic plants, fish, or zooplankton. In cases of rapid recurrence of growth of the blue-green algae, repeated applications are necessary. The lasting effect of treatments, however, may be indirectly increased by vigorous growth of green algae and higher aquatics following the suppression of the blue-greens.

Acknowledgments

The work reported herein was supported in part by the University Graduate School Research Committee with funds from the Wisconsin Alumni Research Foundation and in part by a grant from the Division of Research Grants and Fellowships, National Institutes of Health, USPHS.

The authors are grateful to Professors G. C. Gerloff, W. B. Sarles, and J. G. Dickson, University of Wisconsin, and to the staff of the Wisconsin Conservation Department for advice and assistance in this work, and to Naugatuck Chemical for furnishing the 2,3-dichloronaphthoquinone.

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INVENTORY AND ADEQUACY OF MAJOR COMMUNITY WATER SUPPLIES

Key facilities of the water supplies of the major communities of the United States are inadequate in terms of population growth and industrial expansion it is indicated in an inventory of the facilities released recently by the Business and Defense Services Administration, U. S. Department of Commerce.

The inventory covers 548 water supply systems serving more than 80,000 people in the 560 cities and towns served by community water supplies. The average daily consumption of water in these communities exceeds 12,000 m.g., or an average of 150 g.p.c. This compares with an average of 100 g.p.c.d. in 1910. The maximum day runs as high as 19,000 m.g., or about 230 g.p.c., 60 per cent above the average daily use.

The inventory was prepared by the Water and Sewerage Industry and Utilities Division of BSDA by assembling and correlating information from the Water Resources Division, National Production Authority; U. S. Public Health Service; U. S. Geological Survey; Community Facilities Service, Housing and Home Finance Agency; National Board of Fire Underwriters; American Water Works Association; and the technical press.

Copies of the inventory may be obtained at $0.25 each from the U. S. Department of Commerce, Washington 25, D. C.

SURVIVAL OF *E. COLI* IN WATER FROM GREAT SALT LAKE

By R. S. Fraser and C. I. Argall

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Great Salt Lake is the principal drainage center of the Great Basin. As it has no outlet, its salt concentration is always near the saturation point. This high salinity has led to the general assumption that the water is very bacteriostatic and bactericidal for all organisms other than those of its indigenous halophilic flora (1). The lake therefore has been regarded as a safe depository for untreated sewage from the cities and towns on its inlet systems.

Zobel, Anderson, and Smith (2) found that sewage, soil, and oral cavity bacteria failed to grow on a medium containing 50 per cent lake water, and that only 81.1 per cent of the sewage bacteria were viable on a 10 per cent lake-water medium. No growth was obtained when 23 samples of lake water, seeded with pure cultures of recently isolated *Escherichia coli*, were inoculated into lactose broth or into EMB agar plates. In another of their experiments lake water was inoculated with sewage and "other sources of fresh-water bacteria." One ml. quantities of the polluted water were then planted on standard nutrient agar. They concluded from this experiment that Great Salt Lake destroyed the viability of sewage bacteria almost immediately. Exposure for 1 min. to undiluted lake water killed more than 95 per cent of the bacteria.

In discussing this experiment they injected a note of caution into the interpretation of the results obtained and recognized that "part of the apparent bactericidal effect may be due to the bacteriostatic action of the lake water which is carried over to the nutrient agar with the inoculum." If the results of these studies were questionable because of the limitations of the laboratory methods available at that time, then the assumption that the lake water is bacteriologically safe is also in doubt. Before such a credence can be substantiated, a method is needed that allows the transplanting of organisms from an unfavorable environment to one that is favorable. The method should, at the same time, permit the examination of large quantities of the lake water, as the contaminating material introduced into the lake is soon highly diluted.

The membrane filter technique was found by Goetz, Gilman, and Rawn (3) to be adaptable to bacteriologic studies of ocean water. It was decided to apply this method to determine the survival of *E. coli* in Great Salt Lake water.

Method

A sample of lake water was collected from the south shore of the lake. The water was 92 per cent saturated with sodium chloride, as determined gravimetrically, and its temperature at collection was 8° C. Two 1,000-ml. samples were removed, one being stored at 23° C. ($R°$), the other at 6° C. (Ref°). When the water had reached the temperature of its environment it was seeded with 1-ml. of a 1:1,000 dilution of a broth culture of five strains of recently isolated *E. coli*. The resultant dilution (1×10^{-6}) had been found to

give a bacterial colony count of approximately 100 per ml. A like dilution was made in 1 l. of normal saline to serve as a control. Each of the 1-l. samples was shaken thoroughly and five 1-ml. portions were removed immediately to serve as initial controls. Each portion was introduced into 100 ml. of sterile saline and then passed through a sterile membrane filter under negative pressure. The membranes were then flushed with sterile water to remove any traces of the lake water that may have been retained in or on the membrane and were then incubated on media pads saturated with EHC Albimi peptone M broth (4) at 37° C. in a moist incubator. After 2 hr. on the enriched substrate the membranes were transferred to pads containing EHC double-strength Endo's broth and replaced in the incubator.

In these initial samples the exposure of the bacteria to the lake water was less than 2 min. Other 1-ml. samples of the $R°$ lake water were removed after 30, 60, 90, and 165 min. of exposure. Samples of the Ref° lake water were removed after 1, 2.75, 4, 6, and 8 hr. of exposure. Five of the samples were removed at each time interval, as earlier experiments with the membrane filter had indicated that at least this number of membranes would have to be examined to obtain fairly accurate results (5). All samples were handled in the same manner as described for the initial samples.

In addition to the foregoing, a 100-ml. sample of the $R°$ lake water was removed after 8 hr. of exposure, and passed through a membrane, which was then flushed with 100 ml. of sterile water. A second lot of five membranes was inoculated with the saline control at the end of 8 hr. at 23° C. Two 100-ml. samples of the original—that is, uninoculated lake water—were passed through membranes, which were then flushed with sterile water. An additional control (LW control) consisted of two samples of sterile water, each inoculated with 1 ml. of the $R°$ lake water; these two samples were held at room temperature for 8 hr. before being passed through membranes. All of the membranes were cultured in the manner described. After 16 hr. of incubation the membranes were removed from the incubator, the colonies were counted, and averages for the five membranes from each time interval were computed. The results of this portion of the study are presented in Table I.

TABLE I.—Survival of *Escherichia coli* in Water from Great Salt Lake

Exposure Time		Av. Colony Count per Ml. of Lake Water*			
(hr.)	(min.)	$R°$†	Ref°‡	Saline Control	Lake Control
0	0	91.7	86.8	105	—
0	30	48.2	—	—	—
1	0	50.6	71.4	—	—
1	30	38.4	—	—	—
2	45	22.2	88.6	—	—
4	0	—	59.4	—	—
6	0	—	69.2	—	—
8	0	1.5**	72.6	103	83††

* All results are averages of five membranes except as noted.
† 23° C.
‡ 6° C.
** Only one membrane.
†† Average of two membranes.

Since the results obtained with the Ref° sample showed no significant decrease in the number of viable organisms, another 1-l. sample of the lake water, cooled to 6° C., was inoculated with the broth culture of *E. coli*. After 0, 8, 10, and 12 hr. of exposure at Ref° temperature, 100-ml. samples were removed and passed through membranes. Each membrane was flushed with sterile water and cultured under the same conditions used in the initial experiment, with the exception of the 12-hr. membrane. Here, because of the time involved, it was decided to dispense with incubation on the enriched medium and

TABLE II.—Survival of *E. coli* in Lake Water at 6° C. for 24 hr., Substrates Being Varied*

Exposure Time (hr.)	Individual Membrane Counts per 100 Ml. Lake Water at 37° C.	
	Albimi Peptone M and Endo	Endo Alone
0	289	—
8	256	—
10	267	—
12	—	17
24	165, 144, 123	11, 8, 3

* No growth obtained on two membranes exposed to uninoculated lake water. Colony counts were made under 10X magnification. All colonies observed were typical for *E. coli* on Endo's medium.

the membrane was incubated directly on Endo's broth. When the results of this experiment were read after 16 hr. of incubation, it was decided to run the remainder of the inoculated lake water, which had been held at 6° C., through membranes at the 24-hr. period. The sample was divided into six lots of 100 ml. each. These were passed through membranes; three of them were incubated on Albimi peptone M broth for 2 hr. before being transferred to the selective substrate. The other three membranes were incubated directly on Endo's broth.

The results are given in Tables I and II.

Discussion

The results summarized in Tables I and II show a marked difference in the ability of coliform bacilli to survive in warm ($R°$) and cold (Ref°) lake water. As is evidenced from the results obtained, it has not been possible to obtain highly reproducible results with the membrane filter technique. In this study, individual membrane counts deviated ± 15 per cent from the average of the five membranes run at any time interval. Thus, the difference in counts must be marked to be considered significant. The apparent reduction of 16.5 per cent in the number of viable organisms after 8 hr. of exposure in the cold water (Table I) and the 11.4 per cent reduction for the same time interval in the extension of this study (Table II) are within the range of error of the experiment and cannot be interpreted as a real reduction. Apparently, as shown from these results, about 50 per cent of the organisms are still viable after 24 hr. of exposure to the cold lake water. On the other hand, the counts obtained suggest that few sewage bacteria will remain viable after 8 hr. of exposure to warm lake water ($R°$, comparable to summertime temperatures).

The marked discrepancies obtained in colony counts on membranes that had been incubated on a primary enriched substrate before being placed on an inhibitory and selective medium, and those that were placed directly on the Endo's broth, demonstrate the necessity of a starter medium. This would appear to be essential for the culture of organisms that have been subjected to unfavorable conditions.

The difference in the results obtained in this and the previous studies on Great Salt Lake in which conventional methods were used, gives evidence of the value of the membrane filter technique in bacteriologic studies in which the viability of bacteria subjected to unfavorable conditions is under consideration.

Summary

1. Contrary to previous assumptions, *E. coli* is not killed rapidly by water from Great Salt Lake. At summer temperatures few bacteria will survive more than 8 hr., but at 6° C. approximately 50 per cent will survive 24-hr. exposure to the lake water.

2. The membrane filter technique proved valuable in testing the survival of bacteria in an unfavorable environment, and has provided an excellent means for transferring organisms from an unfavorable environment to one that is favorable.

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PROGRESS REPORT ON A STUDY OF THE MECHANISM OF ANAEROBIC DIGESTION

A research project to characterize and study fat transformation during unseeded, seeded, limed, and accelerated anaerobic sludge digestion has been carried out at Rutgers University by H. Heukelekian and P. K. Mueller. The study was supported by a research grant from the National Institutes of Health, USPHS.

A progress report covering the period October 1952 to September 1953 showed the following:

Parameters chosen included total greases, total acid-free greases, total free fatty acids, unsaponifiable matter, total glycerides, total glyceride fatty acids, total free and glyceride saturated fatty acids, and individual free and glyceride unsaturated fatty acids. For all parameters, methods had to be developed or adapted. Accuracy of the various analyses used was usually better than 90 per cent, with precision usually better than $\pm$ 5 per cent.

Of the total greases in fresh solids, about 67 per cent is free fatty acid, and 33 per cent is acid-free grease; 20 per cent is unsaponifiable matter, 10 per cent is saturated fatty acid. The individual fatty acids are primarily stearic, palmitic, mono- and di-unsaturated, probably oleic and linoleic acids. Oleic acid comprises about 90 per cent of all unsaturated acids. In fresh solids digestion, results indicate that during the acid digestion stage total greases decrease while free fatty acids increase, thus suggesting the breakdown of glycerides. Indications point to immediate utilization of the unsaturated acids. The total glyceride fatty acids also decrease. Unsaponifiable matter shows no significant change.

Seeded sludge digestion showed a steady decrease in total greases, totaling to a 30 per cent loss. There was a corresponding 20 per cent loss in acid-free greases, whereas the total free fatty acids almost entirely disappeared. There was no significant change in unsaponifiable matter. About 70 per cent of the initial glycerides are completely destroyed during seeded digestion. After cessation of maximum gas production, the remaining glycerides continue to be metabolized with the accumulation of unsaturated components in ripe solids. This accumulation may be an important factor in the practice of seeding fresh solids, in that a rich source of growth-promoting substances aids in rapid initiation of gas production.

EFFECTS OF NITROGENOUS COMPOUNDS ON STREAM CONDITIONS *

By Norman G. Flaigg and George W. Reid

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The increase in domestic, industrial, and agricultural use of water and accrued wastes are rendering unusable much of the natural water resources. Many of these wastes contain large quantities of plant nutrients, which promote the growth of organisms in water. These organisms cause undesirable effects in municipal and industrial water supplies and create nuisances interfering with recreational facilities such as fishing and boating. This is particularly true in areas in which there is little natural dilution, such as the Southwest, and even despite what is termed "complete" treatment.

Plant nutrients or fertilizers originate from several sources. Most important of these sources are excess commercial fertilizers applied to the lands, pasture and barnyard manures, domestic sewage, and industrial wastes. The fertilizer elements involved are principally nitrogen and phosphorus. The larger, busier population is putting greater quantities of these elements into the watercourses of the country. Consider, for example, the increase in the use of synthetic detergents in recent years. Few people realize that the most important constituents of these compounds are usually complex phosphates. These substances are not affected by ordinary sewage treatment. Consequently, they flow through the treatment plants and into the streams undiminished in quantity. It is estimated that the phosphorus content of domestic sewage is about twice that experienced before the introduction of synthetic detergents.

Also, fertilizer sales in the United States have increased greatly. Although a relatively small portion of this material reaches the streams under normal conditions, it is possible that heavy rains immediately following fertilizer spreading may wash away appreciable quantities. Sawyer (1) in his studies of several lakes in southern Wisconsin found indications that agricultural drainage was responsible for contribution of fertilizer elements to lakes.

Organisms, algae or phytoplankton, living in the water and flourishing because of excess amounts of plant nutrients may cause tastes and odors in the water and may cause mechanical difficulties in the filters themselves. Tastes and odors are usually difficult and expensive to remove. For these reasons, it is desirable to avoid taste and odor problems. Also, these organisms may convert the inorganic compounds of nitrogen and phosphorus into organic compounds of these elements which may in turn furnish food for other organisms unable to synthesize their own foods directly from the mineral forms. Some of the latter organisms may also cause taste and odor problems.

Naturally, a great many things affect the growth of phytoplankton. Some of the more important factors are food supply, sediment load, stream movement, quantity of water, and the chemical content of the food available. It is generally accepted that the higher plants are able to use both the ammonia and the nitrate nitrogen. Thorne and Peterson (5), however, report that maximum crop production

* Presented at 1953 Annual Meeting, Oklahoma Water, Sewage, and Industrial Wastes Conf.; Stillwater, Okla.; Nov. 16–20, 1953.

seems to require that part of the nitrogen be available in the nitrate form.

Chu (6) found that all the organisms he studied could use both the ammoniacal and the nitrate nitrogen, although the relative nutritional value of the two types differed to some extent depending upon the organism. One organism showed better growth with nitrate nitrogen, whereas the other four showed equally good growth with both types while within the optimum range of nitrogen concentrations. Pennington (7), in experiments with heterogeneous groups of organisms grown in sunken ground pans, found both ammonia and nitrate nitrogen usable by the cultures. Furthermore, he found that nitrites were formed from either the ammonia or the nitrate nitrogen. Welch (8) reported that dilute solutions of nitrite were injurious for some plants and that solutions of nitrite were more toxic than those of the same strength of nitrate.

These papers point out a possible control for algae. Regulation of the amount of nitrogen and phosphorus in the water will influence the growth of plant life therein. Researchers have observed no growth where phosphorus was absent. Phosphorus can be removed by a number of different processes. However, these processes involve additional expenditures for chemicals and equipment.

On the other hand, if algae are unable to use a particular form of nitrogen, that form of nitrogen can be supplied by operation of a normal sewage treatment plant without additional equipment or chemicals. In the nitrogen cycle proteins are changed into ammonia, the ammonia into nitrites, the nitrites into nitrates, and finally the nitrates are converted into proteins, completing the cycle. Raw sewage usually contains ammonia nitrogen in large quantities, whereas sewage treatment plant effluents usually contain lesser amounts of ammonia nitrogen and larger amounts of nitrates, depending upon the process. Nitrites vary from a very small amount in raw sewage to a maximum of slightly more than 0.5 p.p.m. in trickling filter effluents, and are slightly less in the final settling tank effluents.

Evidence from sewage treatment plant practice seems to indicate that the worst blooms of algae are associated with the most highly nitrified effluents. This would seem to indicate that ammonia is not as good a fertilizer as the more highly oxidized forms of nitrogen. It would also seem to indicate that it is desirable to regulate sewage treatment processes so as to produce ammonia nitrogen. Farmers could accomplish the same results by using fertilizers containing ammonia rather than nitrate nitrogen.

The problem is to discover if there is a form of nitrogen which is more readily utilized by the phytoplankton. If there is a preference, measures can be taken to control their growth by changing the nitrogen to forms which they cannot use.

Experimental Procedure

Basically, the problem was one of varying the amount of phosphate and varying the amount and form of nitrogen and observing the growth of algae over a period of time. Chu (6), Sawyer (1), and Welch (8), all report that only very small amounts of phosphorus are necessary to stimulate algal blooms. Because small amounts of phosphates are likely to be present under many conditions in surface waters, they were not considered to be limiting for the purpose of this study.

Therefore, it was decided to run an initial test with a fixed amount of nitrogen available and to vary the amount of phosphorus available. The optimum amount of phosphorus determined in this method would then be used in the study of the growth of algae with various amounts and types of nitrogen.

The standard methods of measuring

algal growth were too slow and laborious for a study of this scope. Literature research revealed that estimation of growth by measurement of the turbidity by a photoelectric cell correlated well with the standard methods. The method of estimation of growth by turbidity is especially applicable when there is an appreciable difference in the size of the individual organisms. Turbidity is not only a function of the number of individuals, but also of the size and density of the cell content. Measurement of growth by turbidity is especially applicable to this study because of the heterogeneous type of growth employed.

Samples of plankton were collected from a small stream southwest of Norman, Okla., and from a small reservoir northwest of Oklahoma City. The reservoir receives effluents from the Bethany sewage treatment plant. Microscopic examination showed that both samples consisted mainly of organisms belonging to the class *Chlorophyceae*. In the first sample the algae was predominantly of the genus *Ulothrix* and the second sample was composed mainly of organisms belonging to the genus *Spyrogira*.

Although the predominant organisms in the samples were those mentioned, actually a wide range of animal and plant life was present. No attempt was made to maintain a bacteriologically sterile condition, since bacteria are always present in nature. Microscopic examination revealed a wide variety of organisms, such as protozoa, ciliates, rotifers, and small crustaceans. These organisms are all present in normal stream conditions and are a part of the regular "chain of life" typical of a fertile water. These heterogeneous collections of organisms were used because it was felt that they were representative of the life in streams polluted by slight to moderate amounts of sewage or sewage treatment plant effluents.

Portions of these algae were placed in jars and set in a window having a southern exposure. At regular intervals the water was changed and a small amount of a commercial plant food added to the water. In this manner, seed colonies were maintained during the course of this experiment.

Three nitrogen forms—nitrite, ammonia, and nitrate—were required. It was considered desirable to avoid the carbonate compound of ammonia because the variation in carbonate ion concentration might affect the carbon dioxide pressure in the test jars. Although the effect of the chloride ion on the growth of algae is not believed to be of significance in low concentrations, it was considered desirable to keep the concentration as low as possible. Consequently, ammonium sulfate was selected to be the vehicle for the ammonia ion. Sodium nitrite was selected to be the nitrogen carrier for the nitrite form because of the stability of this compound. Although the additional amount of sodium was not desirable, the disadvantage was considered to be less than the advantage of having a relatively stable form of the nitrite. Potassium nitrate was selected to furnish the nitrate radical. Gelatin, consisting of pure protein, was used to supply organic nitrogen. In the test in which magnesium was added to the water, magnesium chloride was chosen.

Phosphorus was supplied by a solution of dibasic potassium phosphate. This compound was selected because of its high solubility.

Two controls were provided for each test run. A blank sample of the water used in each test was exposed to the same conditions as the test jars. Another sample of the water without nutrients was seeded with algae in the same manner as the fertilized portions and measurements made of the growth along with the others.

Analytical Results

The first step in this study was to determine the level of phosphate ferti-

lization for the nitrogen tests. Tests were made with a fixed amount of nitrate nitrogen and various amounts of P_2O_5 in a series of test jars. A sample of *Spirogyra* showed maximum growth for 10 and 15 p.p.m. of P_2O_5. It was decided to use 10 p.p.m. of phosphoric acid for the first test.

In the first test, tap water was used. A portion of the colony of *Ulothrix* was placed in a beaker of the tap water and thoroughly dispersed with bubbling air. Three series of seven vessels each were assembled and each dosed with 10 p.p.m. of phosphoric acid. Each series of vessels was dosed with 0 to 30 p.p.m. of nitrogen in steps of 5 p.p.m. One series of jars was fertilized with ammonia nitrogen, one with nitrite nitrogen, and one with nitrate nitrogen. Twenty milliliters of the dispersed algae solution were added to each of the test portions. All of the test portions were then diluted to 500 ml. total test volume. Portions of 500-ml. volume were used because this was a covenient size to work with. The seeded solutions were stirred well and the initial measurements made. The test jars were placed by a window with a southern exposure and allowed to remain undisturbed until the next series of measurements were taken. Watch glass covers were used to reduce contamination from the air. Observations were made over a period of about five days. At the end of this period, microscopic examination revealed that most of the organisms in the jars having the lesser amounts of fertilizers were in a state of decay and the test was discontinued.

The second test was made with well-aerated distilled water. The algal colony, consisting mainly of *Spirogyra*, was used for the second run. The general procedure was the same except that it was arbitrarily decided to use 25 p.p.m. of P_2O_5 in all the test portions and six vessels were used in each series with nitrogen dosages of 0, 10, 20, 40, 60, and 100 p.p.m. In addition to the fertilizers, 10 p.p.m. of magnesium were added to each test portion. Measurements were discontinued at the end of five days, when many of the organisms in the test jars with smaller amounts of fertilizer were found to be decaying.

Run No. 3 was made with the same algae used in run No. 2, but a modified Chu No. 5 nutrient solution (17) was used. The composition of the nutrient solution in grams per liter was as follows: $K_2HPO_4 \cdot 3H_2O$, 0.005; $MgSO_4 \cdot 7H_2O$, 0.025; NaCl, 0.04; $CaCO_3$, 0.01; and $FeCl_3$, 0.001. The algae were grown in Erlenmeyer flasks containing the nutrient solution and 20 p.p.m. of nitrogen as nitrate, nitrite, ammonia, and protein. Crude protein was assumed to be 6.25 times the organic nitrogen content of the gelatin. Measurements of growth were made with the colorimeter over a period of 18 days. No additional tests were made with organic nitrogen because no way could be found to eliminate the turbidity due to decomposition of the protein.

Run No. 4 was made with a modified Chu No. 5 nutrient solution. The composition of the nutrient solution, in grams per liter, was as follows: $K_2HPO_4 \cdot 3H_2O$, 0.005; $MgSO_4 \cdot 7H_2O$, 0.070; NaCl, 0.040; $CaCO_3$, 0.01; and $FeCl_3$, 0.001. Test tubes were seeded with a type of algae that developed on the sides of the jars containing the seed colonies. Test tubes were filled with the nutrient solution and three inorganic forms of nitrogen in concentrations of 0, 10, 20, and 30 p.p.m. Measurement of growth was made directly by placing the culture tubes in the colorimeter, and the measurement was made in terms of percentage of light transmitted. In order to compare the results, values obtained in runs 1, 2, and 4 have been divided into growth values obtained in the absence of nitrogen. These data are shown graphically in Figures 1 through 14. The values represent the increase in

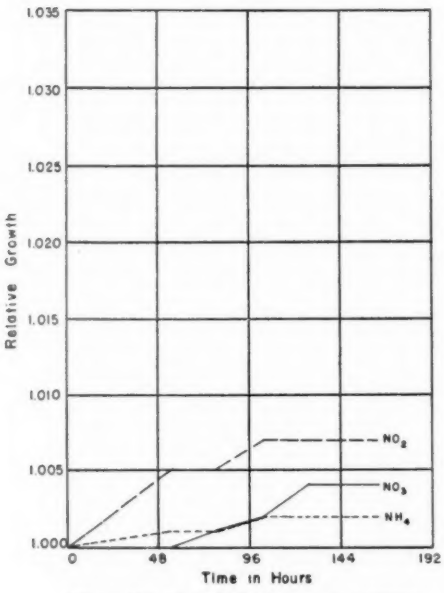

FIG. 1. Run No. I With 5 p.p.m. of nitrogen.

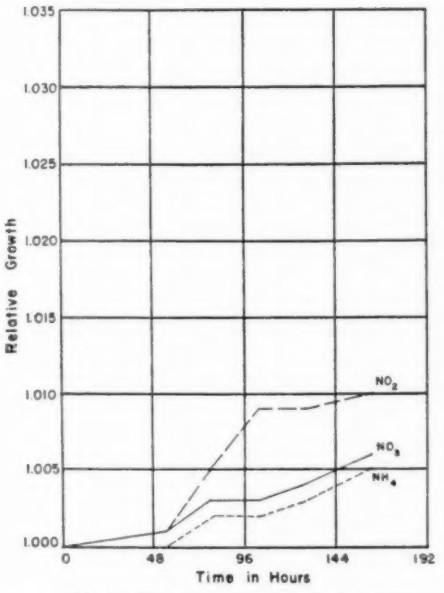

FIG. 2. Run No. I With 10 p.p.m. of nitrogen.

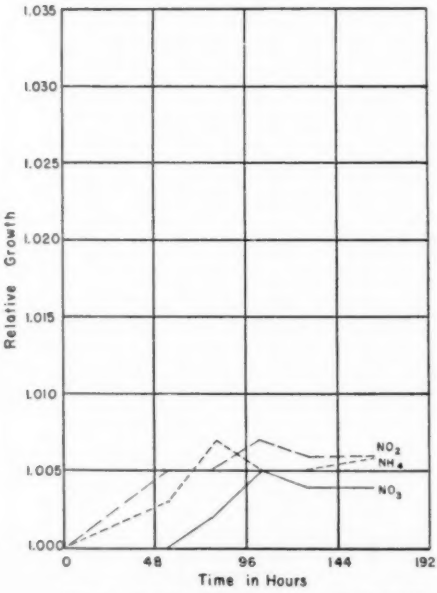

FIG. 3. Run No.I With 15 p.p.m. of nitrogen.

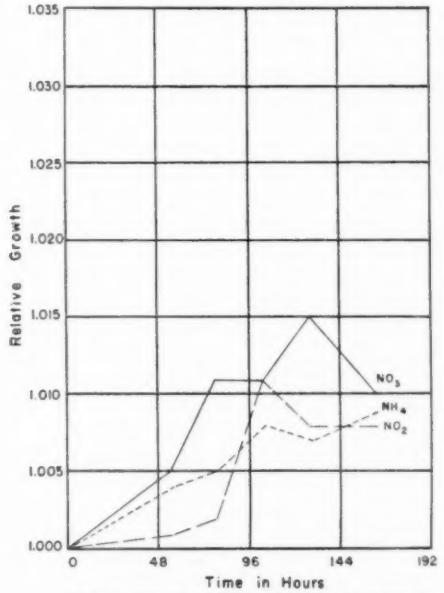

FIG. 4. Run No. I With 20 p.p.m. of nitrogen.

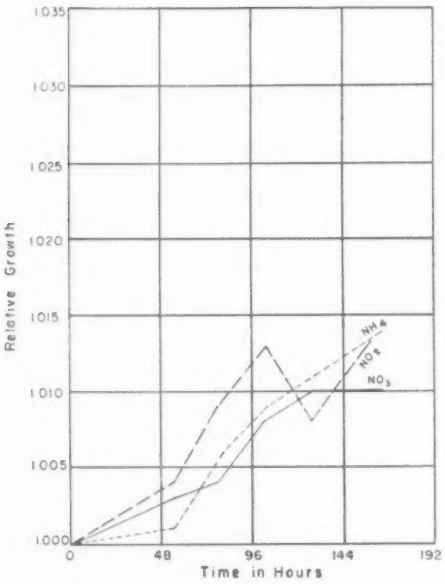

FIG. 5. Run No. 1 With 25 p.p.m. of nitrogen.

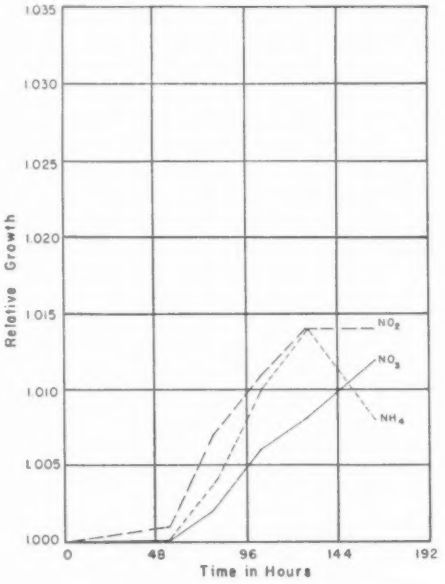

FIG. 6. Run No. 1 With 30 p.p.m. of nitrogen.

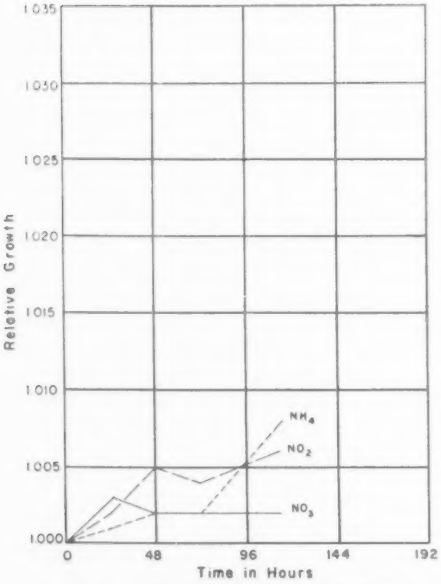

FIG. 7. Run No. 2 With 10 p.p.m. of nitrogen.

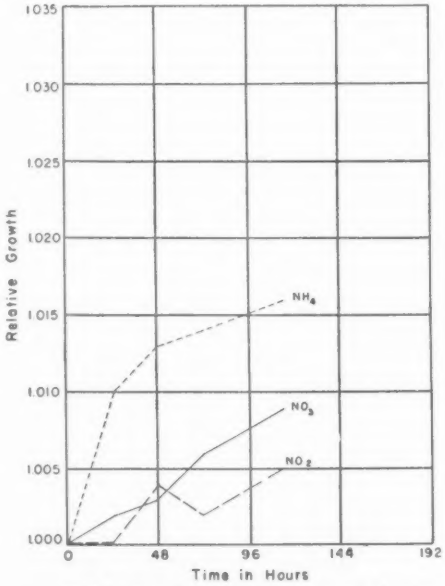

FIG. 8. Run No. 2 With 20 p.p.m. of nitrogen.

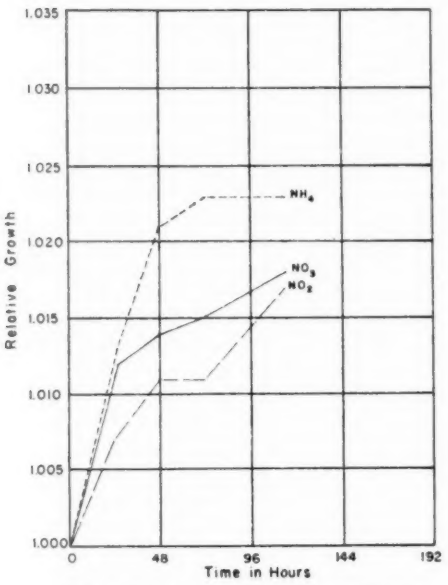

FIG. 9. Run No.2 With 40 p.p.m. of nitrogen.

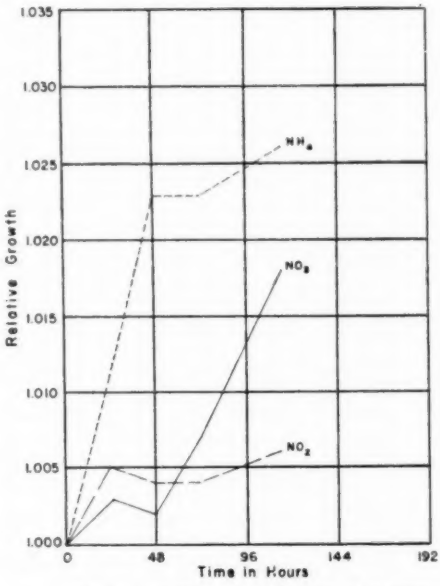

FIG. 10. Run No. 2 With 60 p.p.m. of nitrogen.

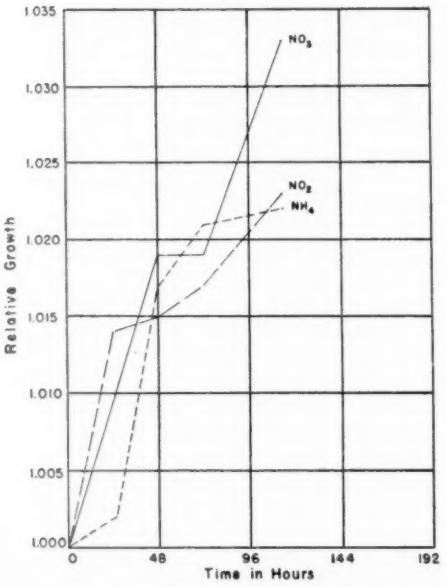

FIG. 11. Run No. 2 With 100 p.p.m. of nitrogen.

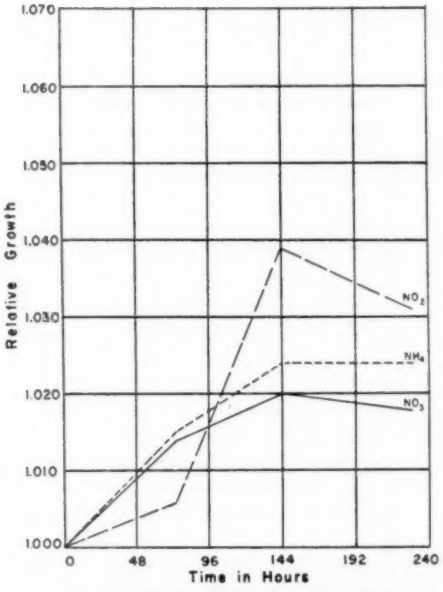

FIG 12. Run No. 4 With 10 p.p.m. of nitrogen.

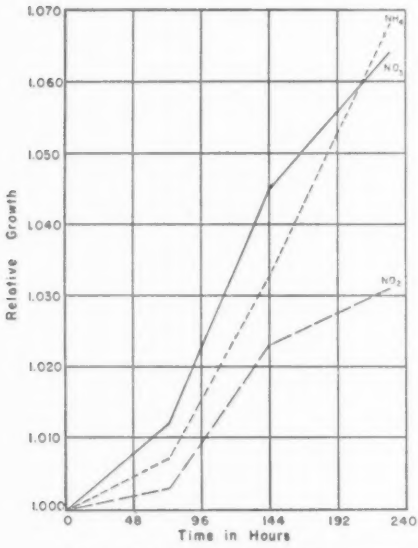

FIG. 13. Run No. 4 With 20 p.p.m. of nitrogen.

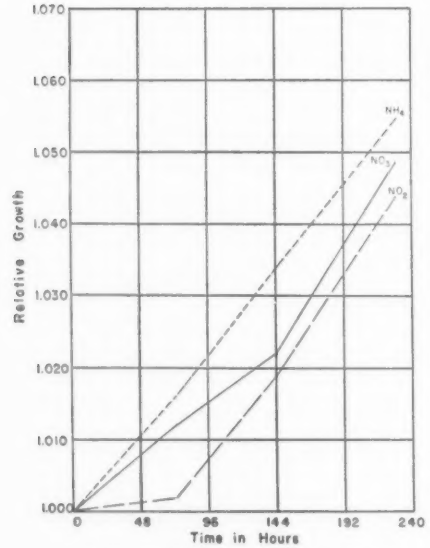

FIG. 14. Run No. 4 With 30 p.p.m. of nitrogen.

growth over that for 0 p.p.m. of nitrogen.

Results of Run No. 3 are shown in Table I. Because this run was not controlled as carefully as the first two runs, and because the results are in question, due to the turbidity of the decomposed protein, no further computations were made with the recorded values, other than a simple average of the three readings. An attempt was made to correct for the turbidity by making a measurement of the supernatant liquid before agitations. This was not completely successful, although the results appear better than might be anticipated. At the end of eight days, the liquid began to clear and take on a greenish cast. Microscopic examination of the green material showed a wide variety of organisms containing chlorophyll. During the eight days, the protein probably decomposed and advanced part way through the nitrification process. It was impossible to observe any growth sponsored directly by the protein because of the turbidity.

Discussion

Figures 1 and 2 give a slight indication that the nitrite form is most readily utilized, with the other two forms about equal in performance. Figures

TABLE I.—Results of Run No. 3, Growth of Algae in Nutrient Solutions Containing Various Forms of Nitrogen

Date	Average Percentage of Light Transmitted with Nitrogen as			
	Protein	NO_2	NH_4	NO_3
4– 7–53	95.4	96.9	96.5	96.4
	100.0[1]	100.0[1]	100.0[1]	100.0[1]
4– 9–53	81.9	95.7	93.9	95.3
	98.3[1]	98.8[1]	97.4[1]	98.9[1]
4–11–53	86.4	95.4	93.4	93.5
	96.7[1]	98.5[1]	96.9[1]	97.1[1]
4–13–53	82.7	95.6	93.8	93.3
	94.7[1]	98.7[1]	97.3[1]	96.9[1]
4–15–53	88.5	94.5	90.5	93.0
	95.1[1]	97.6[1]	94.0[1]	96.6[1]
4–18–53	88.8	93.3	90.6	90.6
	97.9[1]	96.4[1]	94.1[1]	94.2[1]
4–21–53	90.8	90.7	94.2	93.6
	99.6[1]	93.8[1]	97.7[1]	97.2[1]
4–25–53	90.3	95.4	94.2	93.7
	94.9[1]	98.5[1]	97.7[1]	97.3[1]

[1] Adjusted average.

3 to 7, inclusive, indicate that all three forms are about equally effective. Figures 8 through 10 on indicate that the ammonia form is the most active in sponsoring growth. In Figures 8 through 10, also, the nitrite form appears to be less effective than the other forms. Figure 11 shows that ammonia and nitrite nitrogen are about equal in performance, with the nitrate form superior to both. Figure 12 shows nitrite to have a slight superiority over the other two forms of nitrogen. Figures 13 and 14 show nitrate and ammonia nitrogen to be slightly superior to the nitrite form. All of the results show that low concentrations of nitrite nitrogen produce greater growth than the other two forms of nitrogen. It appears that up to about 15 p.p.m. nitrite nitrogen is as good a fertilizer as the ammoniacal and nitrate nitrogens.

Higher concentrations of nitrogen appear to accelerate the growth of algae as long as the concentrations do not become toxic to the plants. Curves depicting the growth with the higher concentrations rise more steeply than those for the lower concentrations. In actual stream conditions this would tend to concentrate the organisms rather than distributing them over a greater reach of the watercourse.

Generally, the results from Run No. 2 show more growth than the results from the first run. The smaller growth for the first run may be due to any or all of the following reasons:

1. Characteristics of the algae.
2. Cloudy conditions during the first test.
3. A greater growth for the 0-p.p.m. condition because of the nitrates present in the tap water.
4. A tendency for the high concentration of sodium ions to inhibit plant growth.

Results of Run No. 3 appear to be about in line with those of Run No. 2. The results from Run No. 4 are for a more specialized type of algae, which developed under the conditions of the study.

The results based on the use of protein by the phytoplankton (Table I) are inconclusive. No growth was observed for the protein-fed algae, although it may have been present. Turbidity, caused by the decomposing of the protein, made observations inaccurate. However, after the protein had partially or completely decomposed, algae were observed to be flourishing as well as in the other test jars.

Apparent reversals in the growth curves are probably due to several factors, or a combination of factors. Probably the most significant factors are the idiosyncrasies of the Lumetron and failure to obtain representative samples. Downward inclinations at the end of the period of observation may be explained by the death and decomposition of the plant cells and by the decrease in the amount of chlorophyll present in the cells.

Conclusions

The authors have reached the following conclusions:

1. There was no significant difference in the use of inorganic forms of nitrogen by plankton typical to streams having moderate amounts of pollution containing fertilizer elements. Therefore, attempts to control the growth of algae in streams receiving sewage effluents by regulation of the degree of oxidation are likely to be unsuccessful.

2. Higher concentrations of nitrogen appear to accelerate the growth of algae as long as the concentrations are not toxic to the organisms. This means that organisms may be concentrated in a shorter length of stream where large amounts of nitrogen are present. For this reason, high concentrations of nitrogen may be more damaging than low concentrations.

3. The nitrite form of nitrogen, which appears less efficient a fertilizer in higher concentrations, may easily change into the ammoniacal or nitrate

form, and become more readily available for plant use.

4. Proteins decompose and become available for plant food if, indeed, they are not already available in their organic forms. This delay may account for the lack of algal blooms where the wastes are not highly nitrified. Further study should be made of this possibility.

Acknowledgments

The authors wish to express their appreciation for advice and consultation to Howard P. Clemens and Louis B. Wolfenson. This work was used as partial fulfillment of the requirements for the Degree of Master of Civil Engineering at the University of Oklahoma.

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Research Activities

A SURVEY OF CURRENT PROBLEMS FOR RESEARCH

By H. Heukelekian and W. H. Wisely

Chairman of Research Committee and Executive Secretary-Editor, respectively, FSIWA

In their selection of problems for investigation, research directors usually give some weight to the extent of the immediate need for knowledge and guidance in the field at large. Consideration of this factor is to be encouraged, so that problems of first concern will receive first attention. Thus will the best use be made of resources and personnel available for research.

The Federation is in an excellent position to serve as the liaison between the research institution and the practicing technologist. This survey is a part of the program to promote and stimulate research in all areas of Federation interest; similar surveys will be repeated from time to time in order to keep apace of the changing picture of stream sanitation.

The data reported here were gathered early in 1954 by means of a questionnaire requesting each recipient to list the problems in wastes disposal or water pollution control held in his opinion to be in greatest need of immediate research and to outline the fundamental information needed to solve these problems. Such questionnaires were sent to a carefully selected list of 145 technologists representing all principal professional segments of the field. Table I is a breakdown of the distribution of the questionnaire and of the response.

The return of only 41 per cent of the questionnaires was somewhat disappointing, particularly because all of those selected for the mailing list were chosen for their demonstrated interest and activity in the field. Although space is not available here to list them all by name, the cooperation of those who did respond is gratefully acknowledged.

Naturally, the character of the returns varied widely, ranging from very general statements to specific project descriptions. Several of the problems call for an answer in the form of the invention of a device to perform special services, and can hardly be considered as research suggestions. Of the studies recommended, most are in the realm of developmental research, although many of fundamental nature are included. In all, more than a hundred problems are proposed.

Especially Pressing Problems

In classifying the returns for presentation it soon became evident that some problems assumed special importance by reason of their repeated mention among the respondents. Some problems received as many as 7 mentions in the total of 60 returns. On the premise that these multiple-mention problems are the most pressing, they are listed herewith, generally in the

TABLE I.—Questionnaire Distribution and Returns

	Questionnaires Distributed	Questionnaires Returned
Consulting engineers	25	13
Sewage works superintendents	27	10
Industrial technologists	23	8
Equipment company personnel	22	4
Research and educational personnel	21	11
Pollution control agency personnel	27	14
	145	60

order of the frequency of recommendation:

1. Synthetic detergents—effects on sewage treatment processes and on sources of water supply; oxidizability of all types; causes, effects, and control of froth formation; effects on grease content and removal; combined effects with shredded garbage from household grinders; comparison of effects in hard-water and soft-water regions.

2. Toxicity in biological treatment processes—with special reference to cyanides, chromium, copper, zinc, nickel, iron, cadmium, oils; limits under shock dosages and under continuous dosages.

3. Toxicity in natural waters—limits for various compounds and wastes separately, as well as synergistic effects of mixtures as discharged to receiving waters.

4. Biological treatment processes—mechanics of removal and synthesis of organic pollutants (use of radioactive tracers suggested); identification of microorganisms, development of optimum-yield cultures; modifications to permit applications to treatment of strong industrial wastes.

5. Stream pollution criteria—development of specific yardsticks for measuring degree of pollution.

6. Pathogenic organisms—development of improved technique for accurate enumeration in sewage and polluted waters; application of molecular filter to determination of *E. coli* and enterococci.

7. Hydrogen sulfide—mechanics of formation; development of effective and economical control methods.

8. Pre-aeration—fundamental mechanics of process; evaulation of advantages, both as to effectiveness of treatment and from standpoint of economics.

9. Aeration—fundamentals of oxygen transfer and diffusion; development of improved methods.

10. Sludge digestion—continued study of mechanism of process as means for accelerated treatment.

11. Sludge concentration—development of improved methods, perhaps by continuous centrifuge, air or gas flotation, or by elutriation; study of viscosity and thixotropy of very dense sludges as a means of developing improved methods of pumping and movement in channels and piping.

12. Undigested sludge dewatering—feasibility of methods of disposal of raw sludge cake; development of improved dewatering methods.

13. B.O.D. determination—continued efforts to develop an accurate rapid standard method applicable to all nontoxic organic wastes.

14. Radioactivity in sewage and sludge—assembly of data on background concentrations of radioactive substances in municipal sewage works; effects on biological processes; hazards to operation personnel.

Other Problems Recommended for Study

All other recommendations reported in the survey have been classified for presentation under major topical headings.

Analytical Methods

1. Toxicity—development of reasonably quick and accurate techniques for measurement.

2. Suspended solids—development of methods for qualitative determination; improved methods for quantitative measurement.

3. Hydrogen sulfide—improved method needed.

4. Taste and odor—development of basic and precise methods.

5. Carbon—development of a rapid and practical quantitative method sufficiently accurate to permit use of C/N ratio as a control in composting of sludge.

6. Dissolved oxygen—development of a recording meter to measure and record continuously the dissolved oxygen content in a flow of water or waste.

7. Physical characteristics—development of a camera, timer, and clock device for providing a continuous record of turbidity, color, froth, floating solids, etc., in a stream or effluent discharge.

8. Invention of equipment or instruments capable of affording rapid and continuous quantitative measurements of dissolved oxygen, B.O.D., cyanides, metal ions, etc.

Sewage Treatment—General

1. Adsorption—mechanism of surface phenomena in biological processes; contact catalysis.

2. Biocatalysts—basic evaluation of enzyme products and bacterial cultures; full appraisal of advantages and limitations.

3. Design criteria—comprehensive study of relationship between actual plant performance and conventional design capacities; economic study of process efficiency in plants as operated.

4. Sewage characteristics—trends in changing composition which merit consideration in future planning.

5. Nitrification—establishment of degree to which it is necessary and desirable to produce nitrates in biological treatment processes.

6. Intermediate treatment—development of economical methods of accomplishing 35 to 75 per cent removal of B.O.D.

7. Antibiotics and growth-promoting substances—study of occurrence in sewage and wastes, and of conditions favoring their formation and destruction; effects on biological processes.

Sewage Treatment—Sedimentation

1. Improved methods of solids removal—study of applications for centrifuges, ultrasonics, tray clarifiers, wet cyclones, etc.

2. Inlet and outlet criteria—development of sound principles for application to gravity separators.

3. Grit removal—study of theory of grit removal from sewage with organic solids and ultimate separation from sludge by special methods.

4. Flocculation and air flotation—appraisal of effectiveness and economics of supplementary means for improving removals by sedimentation.

Sewage Treatment—Biological

1. Activated sludge—study of the basic principles of the process with respect to loadings, oxygen utilization, nutritional factors, reaeration, etc.

2. Trickling filters—study of the basic principles of the process with respect to loading limits, recirculation, media size and depth, efficiency, etc.

3. Underloading—effects of subnormal loads on density of sludge produced by activated sludge or biological filtration.

4. Filter media—search for cheaper material suitable for use in trickling filters.

5. Sewage lagoons—establishment of performance and design factors and of limitations in application.

Sewage Treatment—Sludge

1. Sludge pumping—influence of type of pump, velocities, and pressures on (a) thixotropy of sludge, (b) grease deposition in piping, (c) coagulability and filterability.

2. Solids balance—establishment of dry solids relationship between raw sludge input and digested sludge removed from digesters, as basis for design.

3. Radioactive iodine—effect on formation of C^{14} and on gas production.

4. Phosphates—effects of increased concentrations (from detergents) on digestion.

5. Elutriation—effect on temperature of concentrated sludge and ultimate result in efficiency of filtration.

6. Freezing of sludge—effects on dewatering characteristics.

7. Digested sludge disposal to streams—pollutional effects as manifested by bacterial types and numbers, oxygen balance, bottom deposits, toxicity, etc.

8. Flash-dried sludge—development of methods to control dust, perhaps by

use of additives; development of pelletizing process.

9. Compositing—fundamentals of aerobic decomposition of sewage sludge alone or in combination with garbage.

10. Survival of pathogens—study of possible health hazards from utilization of undigested sludge or sludge undergoing short-period digestion.

Sewage Treatment—Disinfection

1. Mechanism of disinfection by chlorine and other agents.

2. Pathogenic aftergrowths—is there an increase in numbers following chlorination?

3. Tear-gas formation—study of causes when sewage containing certain industrial wastes is chlorinated.

4. Ultrasonic disinfection—evaluation of feasibility.

Industrial Wastes

1. Pure organic substances—compilation of B.O.D. values for reference in the solution of disposal problems when constituents of wastes are known.

2. Composition—compilation of data on chemical components of various types of industrial wastes.

3. Taste and odor-producing wastes (that is, petrochemical, phenol, etc.)—specific determination of types and concentrations which may be responsible for water supply problems.

4. Neutralization—evolution of practical methods of neutralizing dilute acid wastes such as mine drainage and pickling liquor.

5. Ion exchange—broadened application to treatment and recovery of plating wastes, soluble oils, coolants, etc.

6. Spray irrigation—thorough appraisal of fundamental elements, advantages, and limitations.

7. Color removal—development of methods of removing objectionable color from lagoon effluents or from wastes of otherwise minor pollutional effect.

8. Treatment with municipal sewage—economic studies of treatment methods to establish types of wastes best adapted to disposal to public sewers.

9. Pretreatment requirements and methods, flow control, complexing practice to enable treatment with municipal sewage of (a) cannery wastes, (b) textile wastes, (c) water-softening sludge.

10. Biochemical treatment—adaptation of conventional processes to treat strong non-toxic wastes such as petrochemical, refinery, textile, cannery, etc.

11. Plating wastes—evolution of improved methods of treatment and reuse.

12. Brines—investigation of possibilities for by-products recovery.

13. Pulp and paper wastes—evolution of practical methods of by-product recovery and treatment, and odor and color removal.

14. Coal mine drainage—search for practical methods to inhibit and control formation of acid waters.

15. Ammonia wastes—from cuprammonia rayon manufacture—determination of toxic limits, methods of ammonia recovery.

16. Textile wastes—exploration of process modifications to minimize waste disposal problem.

17. Colloidal suspended matter—development of methods for precipitating very fine solids from waters discharged from coal cleaning operations.

18. Solvay process (soda alkali production wastes)—process changes or byproducts recovery methods.

19. Blast furnace gas washer wastes—effects on receiving waters; methods of clarification.

20. Laundries, restaurants—basic studies aimed at treatment of wastes produced in unsewered locations, which problems are complicated by very high concentrations of synthetic detergents in wastes.

Water Pollution

1. Stream velocity—employment of radioisotopes for determining time of flow.

2. Bacterial loading—re-appraisal of

standard maximum density of coliforms in sources of public water supply.

3. Water quality criteria—establishment of reliable criteria for various usages of receiving waters, especially dissolved oxygen levels necessary to maintenance of all forms of aquatic life.

4. Turbidity and temperature—effects in limiting the productiveness and usefulness of natural waters; effect of turbidity on photosynthesis.

5. Fish life—basic field studies of the relationship between water quality and the growth and reproduction of fish.

6. Natural purification—basic study of the biological factors governing the assimilative capacities of receiving waters for non-toxic organic matter; exploration of causes for phenomenal ability of some streams to assimilate pollution.

7. Tidal estuaries—derivation of laws defining rate of change of water due to tidal activity; evaluation of natural purification by reaeration, photosynthesis and other factors.

8. Stream aeration—exploration of the feasibility of artificial aeration of polluted streams.

9. Agricultural poisons—determination of the pollutional effects of new insecticides as related to various water uses.

10. "Beneficial" pollution—evaluation of possible constructive effects which might accrue from the discharge of organic wastes to streams, such as food supply for fish, inhibition of algae growths, bactericidal action, etc.

11. Natural phenols—investigation of possible natural sources of phenol in streams, as from decaying leaves.

12. Biological studies—perhaps employing model streams—designed (a) to yield biological indices of pollution, (b) to evaluate the effects of pollution abatement practices on affected streams, and (c) to supply fundamental knowledge of the effects of pollution on marine areas and estuaries.

Miscellaneous

1. Sewer hydraulics—establishment of the true relationship between the values of n and R to correct the general assumption that n remains constant at all depths of flow in sewers.

2. Diffusion of chemicals—determination of flow distance required for complete diffusion of chemicals fed in pulsating dosages into pipes flowing under pressure.

3. "Wrap-on" meter—for estimating flow in pipes flowing full without requiring the "cutting-in" of any metering element or device.

Conclusion

A survey made and reported in 1953 (see THIS JOURNAL, **25**, 9, 1077) yielded a list of 69 institutions that are equipped to engage in research into problems relating to water-borne wastes disposal. Many other institutions known to be conducting such research did not participate in the survey. A substantial number of the problems recommended here were reported by these laboratories to be already under study, and it is hoped that all of them will eventually be given attention.

Plant operation personnel are also urged to review the problems that are listed, for some of the answers may be attainable through analysis of plant-scale data, or from special studies in operating plants. For example, preaeration facilities are provided in many modern plants, yet there are almost no data on the true advantages and limitations of the process.

Surveys similar to this one are planned to be conducted periodically henceforth, probably every two years. In the meantime, however, all readers are urged to forward at any time their suggestions for needed research. Such ideas will be passed on to research administrators as their importance and urgency may dictate.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

IS PREVENTIVE SEWER MAINTENANCE JUSTIFIED? *

BY CEDRIC WEBSTER

Superintendent, Menlo Park Sanitary District, Menlo Park, Calif.

A year or two ago the maintenance crew of the Menlo Park Sanitary District was engaged in cleaning out a section of one of the 10-in. lines that had been in use for half a century or so—and probably during that time had never once been touched. Certainly it had never been cleaned out, for in addition to removing almost a ton of rock and gravel the crew salvaged some two dozen knives and forks, several sets of false teeth, a pocket watch, $6.40 in small change, and two saloon checks. The saloon checks were unusable, for the saloon itself had disappeared with the advent of the 18th Amendment. The knives and forks went for scrap; the false teeth are being saved for emergency service; the rock went to fill up a hole in the corporation yard, and the $6.40 went into somebody's pocket. This experience should clearly demonstrate the economic justification of preventive sewer maintenance!

Preventive maintenance is "a planned program of inspection, servicing, and repair of the sewer system." However, the term means "the acts and works which are necessary to keep and maintain a system of sewers and sewer appurtenances in proper operating condition and protecting them, insofar as is possible, from the ravages of time and abuse." It consists of seeking out those points of potential weakness which are inherent in every system and eliminating them wherever possible. It consists of correcting troubles while they are small, rather than waiting until they become critical. In a word, it consists of the application of common sense to sewer maintenance.

It is well known that an ounce of prevention is worth a pound of cure. No mechanic worthy of the name waits for the breakdown of his machine before servicing it. A sewer system, playing as it does a far more vital role in man's welfare than any machine, and costing a great deal more, is certainly entitled to at least equal consideration, insofar as proper maintenance will assure proper operation of this second most vital public utility.

It is difficult, if not impossible, to appraise the value of a properly operating sewer system in terms of economics, which concerns itself with the conditions and laws affecting the material means of satisfying man's desires. The true value of a properly operating sewer system can only be assessed in terms of man's health, comfort, and welfare.

One can attempt an economic analysis of this subject by comparing the dollar and cents cost of practising preventive maintenance, as against maintaining the system in a hit-or-miss fashion. This presupposes the existence of voluminous and accurate records which,

* Presented at 1954 Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

at least in the case of the Menlo Park Sanitary District, are not available.

Such figures as are available, however, indicate that our maintenance labor costs on a per-mile basis were substantially the same in 1953, when an attempt was being made to practice preventive maintenance, as they were in 1949, when little more than emergency service was being performed. Maintenance salaries in 1949 were approximately $9,000, which amounts to approximately $11,250 when adjusted to 1953 pay scales. In 1949 the District had some 180 mi. of main sewers and laterals to maintain. Maintenance salaries were approximately $15,000 in 1953, when there were some 240 mi. of main sewers and laterals to maintain. On this basis it cost a little more than $62 per mile in 1949 and the same in 1953.

No claim is made as to the absolute accuracy of these figures, nor do they tell the whole story of what is being attempted. A far truer picture is conveyed by the fact that in 1949 there was an average of between 15 and 20 main line stoppages a month, whereas during the first four months of 1954 there was an average of less than three.

Another factor affecting the economic picture, and having a direct bearing on the value of preventive maintenance, is the losses caused by deterioration of the system. The useful life of a machine or a sewer is pretty much a direct function of the type of maintenance it receives. The presence of hydrogen sulfide, roots, and breaks in the pipe itself, all take their toll in shortening the useful life of the system. Proper preventive sewer maintenance will aid in reducing the excessive costs created by infiltration of surface and ground water into the sanitary system. The presence of excessive infiltration creates problems, not only in the collection system, but also at the treatment plant. Proper preventive maintenance also will aid in reducing the losses created by the flooding of homes, offices, and industrial plants. Areas where damage claims have mounted know only too well how quickly and how drastically these claims are reflected in their insurance rates.

Possibly it is not generally known that the San Francisco Appellate Department of the Superior Court of the State of California, in a ruling made on March 23, 1953, which, when stripped of its legal verbiage says: "Gentlemen, you had better start practicing preventive sewer maintenance, or else!" This opinion states that the sewer authority is under an obligation to display reasonable diligence in making inspections for discovery of unsafe and defective conditions. It goes on to state that the municipality cannot escape liability because it was unaware of a potentially dangerous condition. It must at all times display vigilance in inspection, care, and maintenance.

The opinion states:

"In the case before us, the city's sewers were potentially dangerous and the city was under an obligation to make reasonable inspections so as to correct any defective conditions.

"Where the authorities who have planned and constructed an improvement have knowledge of circumstances which reasonably might be expected to result in a dangerous condition as a natural and probable consequence of the work, such authorities are put upon inquiry, and it follows that it is incumbent upon them to make inspections commensurate and suitable with the nature and character of their knowledge of the peril which should be avoided."

Whether preventive sewer maintenance is or is not economically justified is of minor moment. Even the fact that court opinion may well be considered as requiring its performance is of secondary importance. The primary reason for practicing preventive maintenance is that it is the only means of assuring the proper operation of a municipality's second most vital public utility.

BIOCATALYTIC ADDITIVES IN WASTE TREATMENT *

By J. E. McKee, *Chairman*, Ben Benas, W. L. Henderson, R. R. Kennedy and E. Pearson

Special Committee on Enzymes and Biocatalysts, California Sewage and Industrial Wastes Association

During the past two or three years, operators, chemists, and engineers in the field of waste treatment have been hearing about several new biocatalytic products. The firms marketing and distributing these products have been active in their promotion and enthusiastic in their claims of the effectiveness of the new additive substances in alleviating many of the troubles that beset industrial and municipal waste treatment works. These claims have led many members of the California Sewage and Industrial Wastes Association to seek from research institutions, leading consulting engineers, and well-known technical journals some reliable information regarding the efficacy of biocatalytic additives. Because such information is still somewhat meager, a Special Committee on Enzymes and Biocatalysts was appointed in January 1954 to investigate the use of these substances locally and to report to the membership of the Association at the 1954 Annual Meeting.

Scope, Limitations, and Procedures

This investigation was limited by the short time available for independent laboratory research by the committee members. In lieu thereof, it was decided to poll the membership of the Association and to assemble from these numerous sources all possible information describing operating experiences, laboratory experiments, and field observations. In addition, advertising literature was scrutinized and the few articles in technical publications were reviewed.

The questionnaire sent to many members of the California Sewage and Industrial Wastes Association included the following interrogations:

1. Have you used or experimented with any enzymatic or biocatalytic substance at your plant?
2. What is the name of the substance used and the organization through which it was supplied?
3. How did you happen to hear about it and why did you decide to use it?
4. How much did it cost?
5. What unfavorable conditions at your plant, if any, led you to use this product?
6. What results did you experience from the use of this product?
7. Have you performed any laboratory or pilot-plant experiments with this substance, and if so, what results were obtained?
8. Do you plan to continue using the substance?
9. Do you have any other comments or suggestions for the committee report?

It is a tribute to the membership of the Association to note that operators and superintendents from 61 plants returned questionnaires. Of these, 43 replies indicated that biocatalytic additives had not been used or investigated. The remaining 18 members who had had some experience with these products kindly contributed most of the information on which this report is based. The Committee acknowledges with thanks the cooperation of all members who replied to the questionnaire.

Characteristics of Additives

A biocatalyst is a substance that activates or stimulates a biochemical re-

* Presented at 1954 Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

action. Foremost among biocatalysts are the enzymes that are produced by bacteria to break down complex substances into forms that are available for energy and the synthesis of protoplasm. The biocatalytic additives that are being proposed for waste treatment are reported to contain concentrated mixed enzymes, preserved microorganisms, and/or some trace minerals.

The information submitted to this Committee indicated that five biocatalytic additives had been tried in California. These products are designated throughout this report by letters in order to avoid favorable or unfavorable comparisons by advertised trade names.

Substance A was employed or investigated at five plants. Selling at a price of $4.00 to $4.75 per pound, it has been reported to comprise numerous enzymes obtained from selected organs of certain fish and possibly from other sources. The laboratory staff at the Hyperion sewage treatment plant analyzed this substance and also their digester supernatant for gastric protease, pancreatic protease, tripeptic protease, urease, amylase, lipase, peptase, and invertase. The digester supernatant contained all of these enzymes in concentrations equal to or greater than those of substance A, with the exception of amylase, which was greater in A. There was no urease in A, but the supernatant contained large amounts of this enzyme.

Substance B, used or investigated by 10 plants in this survey at costs reported to range from $3.00 to $4.95 per pound, is advertised to include more than 70 enzymes contained in powdered dessicated organs of numerous animals and fish, bacterial cultures, fungi, molds, and tissues of several plants.

Substance C, a liquid product selling at about $0.90 per gallon, was used in six plants for which information has been submitted. Reported to consist primarily of enzymes of vegetable origin, it was compounded and used originally as a soil-conditioning agent and it has been proposed for application to accelerate decomposition of compost heaps and waste agricultural products.

The other two substances, D and E, were liquids. Each was reported by one operator only and it is believed that their use and distribution are not widespread. No information was available as to their source or content.

A sixth substance, F, widely used in other parts of the country but not listed in the questionnaires returned from California and Nevada plants, is reported to comprise dry preserved living microorganisms from natural sources, with enzyme systems and trace minerals to improve and accelerate biological processes. The sources of these substances are not revealed, but it is believed that the origins are somewhat similar to those of Substance B. Priced at $3.10 to $3.25 per pound, it is available in five or more different formulations for specific purposes.

Attributes Claimed By Distributors

A survey of the advertising literature and the questionnaires revealed that the following attributes have been claimed for certain products in specific situations. It is asserted or otherwise claimed:

1. In collecting sewers and pumping plants, that biocatalysts will reduce odors and hydrogen sulfide concentrations; and that one substance will "remove dead organic solids from sewer lines."

2. In primary settling tanks, that one substance "liquifies a large portion of the colloidal solids" and the carrier used "serves as a flocculating agent, giving greater clarification"; that another substance "improves flocculation through the effect of its colloidal electrolytes" and improves oxidation "by increasing aerobic bacteria activity in the sedimentation"; that one substance "positively liquidizes sewage by enzyme action"; and that another has the

"specific ability to flocculate sewage" and "to produce rapid settling."

3. In trickling filters, that one material increases the operating efficiency, that another promotes healthy algal growth and minimizes ponding, and that a third reduces the suspended solids and B.O.D. in the effluent from a trickling filter plant.

4. In the activated sludge process, that one substance favors the "rapid production of floc to accelerate settling rate" and reduces the suspended solids and B.O.D. in the effluent.

5. In lagoons or oxidation ponds, that an additive eliminated sludge blankets on lagoons, gave increased percolation rate, improved the dissolved oxygen, and produced only a paper-thin sludge in dried-up lagoons.

6. In digestion tanks, that one substance "improves disintegration by accelerating the breakdown of solids in digesters. It is capable of increasing gas production as much as 300 per cent"; that it reduces scum formation and stabilizes the pH in digesters and Imhoff tanks, giving rapid and even sludge digestion; that it increases gas production by 18 to 35 per cent, in fact, "there will always be an increase in gas production"; that it reduces the volume of digested sludge and its volatile content with reduced solids in the supernatant; and that another additive improves the pH and increases gas production in digesters, with less solids, odor, and B.O.D. in the supernatant.

7. In sludge drying, that one additive reduces sludge drying time by 50 per cent, reduces sludge odors, and favors free-flowing sludge and easier sludge pumping; and that another substance improves the action of sludge lagoons.

8. In a miscellaneous category, that one material contains many enzymes "that do not occur in normal sewage treatment" and that it "is capable of digesting sterile sewage, doing so in less time than is accomplished in properly designed sewage digestion plants"; that operation of a new plant with another is a definite advantage and "you won't experience 'starting trouble' because the 'seeding' of your plant will take place with the most efficient organisms for each process"; and finally, in a modest note, that one additive "is not a cure-all."

In contrast with the claims of the distributing agencies, it is interesting to note the unfavorable local conditions that led operators to use these products. Difficulties with digestion tanks far outnumbered all other complaints, ranging from slow digestion to heavy scum blankets with low pH, foaming, poor gas production, and/or low-quality sludge. Several operators reported grease clogging of sludge lines; at two plants the biocatalysts were tried in order to alleviate odors and hydrogen sulfide in the influent sewers. An attempt was made to make dried sludge easier to grind at one plant; at another the additive was used merely to see if it would increase percolation from storage lagoons. None of the operators used these substances to improve sedimentation, aeration, or the quality of the effluent.

Effects of Additives

The results of the questionnaires and a survey of the literature revealed the following data and other information:

1. Collecting Sewers and Pumping Plants

Substance C was tested in part of the sewer system of the City of San Diego to determine if it would assist in any way in lowering or controlling the generation of hydrogen sulfide. Dosage was maintained at a rate of 20 p.p.m. for five days and then increased to 40 p.p.m. A careful record of the total sulfides in the sewage arriving at a control point was kept during this test and at no time was any appreciable reduction in sulfides observed.

At the Orange County Joint Outfall Sewer laboratory, one of the Committee

members evaluated substance D, which had been proposed for sulfide control in a trunk sewer serving a cannery. At the recommended dosages of 50 and 100 p.p.m., the sulfide development proceeded as rapidly as in the untreated control.

Another operator used a total of 190 gal. of substance C over a period of 15 days to try to control hydrogen sulfide in a force main, with no success. He is now using copperas, which has been successful in reducing dissolved sulfides from 6 p.p.m. to 0.5 p.p.m. At another plant, substance B was used in an attempt to clear sewer lines with "absolutely no favorable results at all."

According to McKinney (1), biocatalysts are not indicated for the collection system if they increase the rate of biological action. The only way to reduce anaerobic action during collection is to keep biological action at a minimum, and this can be accomplished best by the addition of bactericidal agents early in the collection system.

2. Oxidation Ponds

At Modesto, Ray (2) claims to have used substance C successfully as a means of odor control. He also found that it apparently improved the operation of oxidation ponds used for canning wastes, by eliminating sludge blanket formation on the ponds, improving dissolved oxygen and algal growths in the ponds, and increasing the rate of percolation from the ponds. Another operator who was familiar with this situation reports that the apparent improvements at the time substance C was used may have been due to natural causes and not to the additive. In the absence of detailed controlled data it is difficult for the Committee to evaluate either of these contentions.

At Fresno, substance C was used to see if it would increase the percolation from the storage lagoons. Water disappeared about 50 per cent faster from the lagoon that had been treated than from the untreated lagoon. The operator reported, however, that it was much cheaper to scarify the lagoons every three years than to purchase this additive. Scarifying increased the percolation by 400 to 500 per cent.

3. Trickling Filters

At San Leandro, the superintendent reported that an artificially induced growth had caused 75 per cent of the filter area to be ponded. Three or four days after adding 1 lb. of substance B to sewage spread over the filters, he observed that ponding had cleared up entirely and that normal growths had appeared. Without an undosed filter for comparison, it is not known whether the improvement was due to the added substance or to other factors.

4. Activated Sludge

McKinney and Poliakoff (3) studied the effects of two different biocatalytic substances on the establishment of new activated sludge. It was found that the additives did not increase the rate at which biochemical equilibrium was reached over that of a sewage-seeded control, and they did not increase the rate of B.O.D. removal once equilibrium was reached. Attention is invited also to item 8 ("Aerobic Stabilization") hereinafter.

5. Sludge Digestion

Numerous tests have been performed by engineers and operators in California to determine if biocatalytic additives had any effect upon gas production, pH, alkalinity, and/or volatile acids in sludge digestion. With one exception, all of the experiments were neutral, indicating that the additive was neither beneficial nor harmful to sludge digestion. In the exception, the operator had been having difficulty with gas production and pH, so that he needed supplementary fuel, and he had been adding lime quite heavily. Stopping the lime, he applied 104 lb.

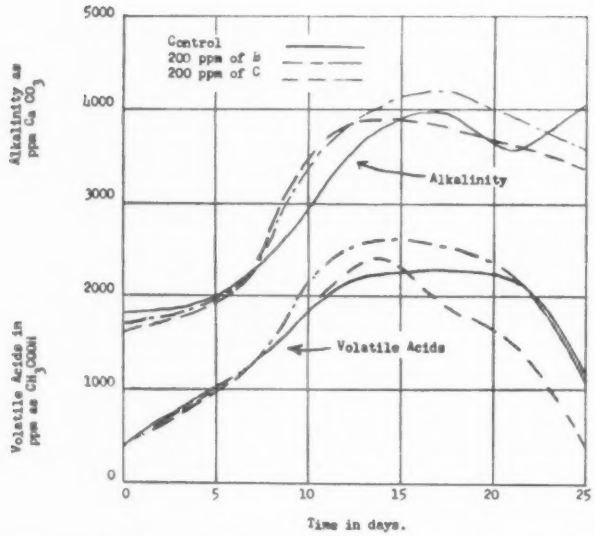

FIGURE 1.—Effect of biocatalytic substances B and C on volatile acids and alkalinity in digestion of seeded sludge (from Sewage Treatment Division, Dept. of Public Works, San Diego, Calif.).

of substance B in one batch, followed by 3 lb. per week for 13 weeks. Within 21 days after the batch treatment, gas production had improved enough to supply the boiler. The operator discontinued the additive after 13 weeks and apparently has not needed it since. Whether the improvement in gas production was due to the additive or to the cessation of lime dosing is not definite.

In contrast, two operators ran pilot-plant digesters with sludge plus biocatalytic additives, and a control sample without these substances. One used A and C, the other B, and in all cases the production of gas was the same in dosed samples and controls. Another operator used 150 lb. of substance A in the digestion tank without improvement in gas production. Later he used 230 gal. of substance C and achieved a very slight increase in gas production, but it was short-lived. Persistent in his search for a palliative, he then tried 1,300 gal. of substance E and, although this application was followed by a scum break-up of major proportions, there was still no increase in gas production.

At San Diego, digestion tests were performed with samples containing two-thirds raw sludge and one-third digested sludge. To one sample, 200 p.p.m. of B were added and to another 200 p.p.m. of C. A third sample was used as a control. As shown in Figure 1, there was no significant difference in volatile acids or alkalinity in the three samples during the 25-day test.

A member of this Committee experimented with concentrations of approximately 1,500 and 3,000 p.p.m. of substance A in 2-l. samples of actively digesting sludge with the following initial characteristics:

pH	6.9
Total solids	2.57%
Volatile solids	1.43%
Ash	1.14%
Volatile acidity	1,570 p.p.m.
Alkalinity	3,700 p.p.m.

From Figure 2 it is noted that the pH values in both of the dosed samples and the control increased steadily, reaching a rather high level in 8 days. This increase is typical of digesting sludges at this plant. The increase in volatile acidity for the dosed samples (Figure 3) appears to indicate that the added material had contributed supplemental organic matter which the normal sludge organisms proceeded to digest. After three days the volatile acid contents were not significantly different, indicating that the additive had no effect on the course of digestion other than the contribution of more organic material to digest.

This member also conducted tests with substance B at a dosage of approximately 30 p.p.m. in very sour nondigesting sludge. Observations during 41 days of digestion indicated that there was no significant difference in pH or volatile acids between the dosed and undosed samples.

The effect of 20 p.p.m. of substance B was also tested by another Committee member under conditions of thermophilic digestion (126° F.) of unseeded East Bay Municipal Utility District sludge. The analyses conducted at the start of the experiment and again after 22 days on dosed and undosed samples (Table I) reveal that there was relatively little change in the character of the sludge in either digester; however, the greater change occurred in the untreated sludge.

Similar thermophilic digestion experiments were performed with a mixture of digested sludge and a high-protein industrial waste that had become "stuck" as a result of excessive acid production. During a 28-day period no significant digestion occurred either in the digester containing 20 p.p.m. of substance B or in the control.

The effect of substance B on raw sludge, with an ether-soluble content of more than 35 per cent of the total solids, was evaluated by the Chief Sanitary Chemist of E.B.M.U.D. The biocatalytic activity was followed by noting the increase in the acid concentration, which is a measure of the decomposition of raw sludge. The results (Figure 4) indicate that neither substance B alone nor B with hydrocarboncellulase [*sic*], both in varying concentrations, produced a greater activity than did raw sludge alone during a 68-hr. test. At the end of the test,

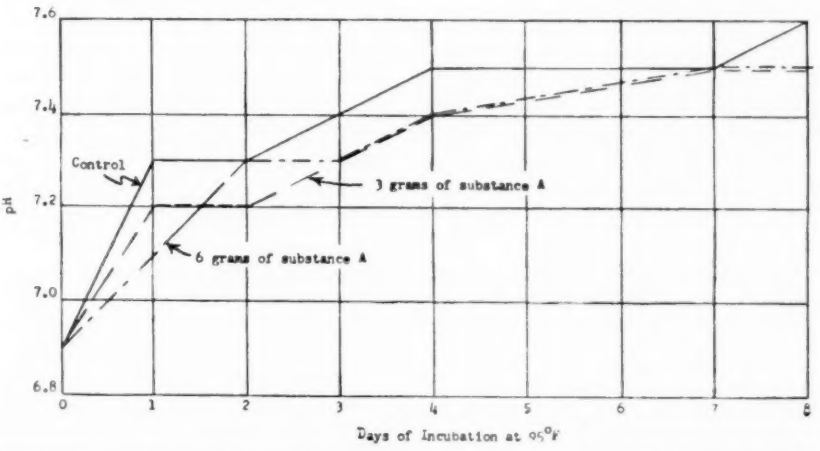

FIGURE 2.—Effect of biocatalytic substance A on the pH of actively digesting sludge (from laboratory of Orange County Joint Outfall Sewer).

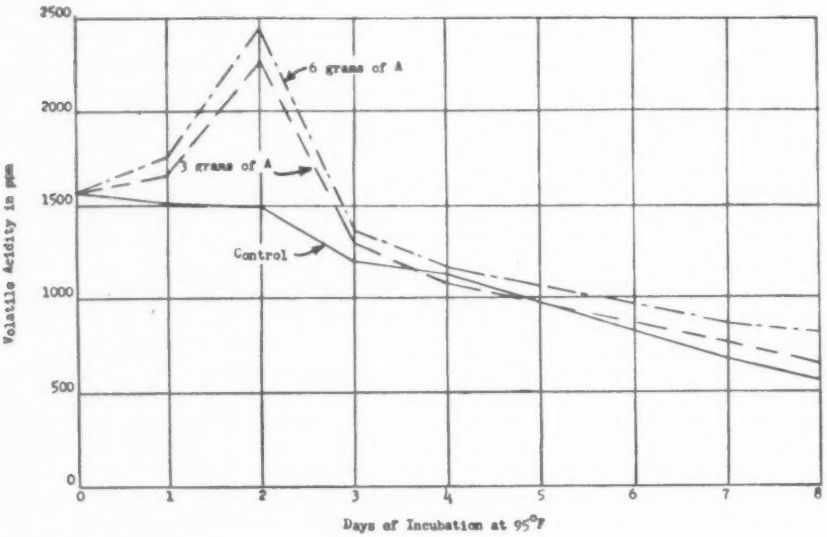

FIGURE 3.—Effect of biocatalytic substance A on the volatile acids in actively digesting sludge (from laboratory of Orange County Joint Outfall Sewer).

the volatile solids content of each sample was determined, with the results shown in Table II.

In view of the fact that there was only one determination of the volatile content of the raw sludge, the slight changes in the percentage of volatile matter in the final samples are not statistically significant.

Another series of tests, run with sludge collected directly from the bottom of a settling tank, revealed no effect whatsoever by substance B, with or without added hydrocarboncellulase.

Heukelekian (4) experimenting separately with five specific enzymes and a mixture of all five, found that they did not increase the gas yield, affect the pH, or change the reduction of volatile solids in properly seeded sludge. He also determined that two of the biocatalytic additives referred to in this report had no significant effect on the B.O.D. of supernatant liquor of digesting samples of fresh sterile solids or fresh non-sterile solids. According to Bryan (5) on the other hand, the application of 10 lb. of substance F to an overloaded digester, followed by daily feedings of 2 to 5 lb., caused the pH to rise and the suspended solids and B.O.D. in the supernatant to decrease.

TABLE I.—Effect of Biocatalytic Additive (B) on Domestic Sewage Sludge during Thermophilic Digestion (East Bay Municipal Utility District)

Sludge	Tot. Sol. (%)	Vol. Sol. (%)	Vol. Acids (p.p.m.)	Alkalinity (p.p.m.)	pH	Vol. Sol. Red. (%)
Raw (control)	6.85	5.00	1,450	1,800	5.7	—
After 22 days batch dig.:						
Control	5.55	3.97	2,850	2,650	5.6	20.6
Sludge plus 20 p.p.m. B	6.50	4.90	3,200	2,220	5.6	2.0

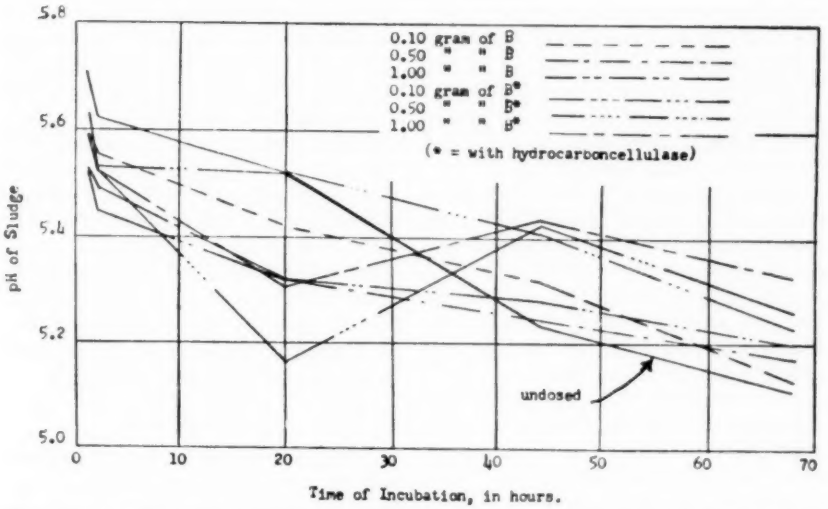

FIGURE 4.—Effect of biocatalytic substance B on the initial stages of digestion of raw sludge (50 grams) (from East Bay Municipal Utilities District).

6. Scum Blankets and Grease Clogging

Four operators have experimented with substance B to dissolve grease in sludge lines or to break up scum blankets, two with some apparent success and two with none. One of the unsuccessful operators also dosed two jars containing grease taken from a clogged sludge line with the recommended quantity and with a double dose. During a month at about 70° F. no reduction in grease was noticed. In the other unsuccessful attempt, substance B was pumped directly into a pipeline that had been clogging, first in a large batch and later in daily applications. There was no apparent effect upon the frequency at which the sludge line plugged and also no apparent change in consistency of the plugging sludge. This substance did not free a plugged sludge line nor prevent the plugging of a line.

At another plant, this substance was put into a 4-in. pipe almost completely plugged with grease and enough water was added to fill the pipe. After 24 hr. most of the grease was emulsified. The third operator found that since the batch addition of 1 lb. of substance B to a 6-in. sludge line, no clogging has occurred, although this line had formerly clogged frequently.

At Redwood City a heavy scum blanket formed in the digester while the sludge mixers were being repaired. Initially, 50 lb. of substance B were added, and 8 lb. per week for six weeks,

TABLE II.—Results of Addition of Biocatalyst B to Raw Sludge at East Bay Municipal Utility District Sewage Treatment Plant

Weight of Sludge (g.)	Weight of Substance B (g.)	Total Solids (%)	Total Vol. Solids (%)	Percentage Volatile
50	0	10.8	8.23	76.2
50	0.05	10.3	7.70	74.7
50	0.10	10.2	7.60	74.5
50	0.25	10.7	8.10	75.7
50	0.50	11.1	7.43	66.9
50	1.00	11.6	8.68	74.8
50	0.05[1]	10.5	7.85	74.8
50	0.10[1]	10.5	7.80	74.3
50	0.25[1]	10.4	7.75	74.5
50	0.50[1]	11.0	8.15	74.1
50	1.00[1]	12.1	8.95	73.9

[1] Including hydrocarboncellulase added to substance B.

then 8 lb. per month. After six months the scum blanket was well dissolved. At the time the additive was used, however, the mixers were also repaired and put back in service, so it is not known which event is responsible for dissolution of the sludge blanket.

The application of 25 lb. of substance B to a 300-cu. yd. accumulation of grease, scum, and tomato skins on the bottom and sides of a digester at San Leandro appeared to loosen the mass in five days and allow it to be broken up with a fire hose after previous efforts with the hose had been ineffective.

At Oceanside, the application of 1,300 gal. of substance E to the digestion tank was followed by scum breakup of major proportions.

7. Sludge Drying and Disintegration

Sludge from the digester at San Leandro, previously described, after the application of substance B, was drawn to open drying beds. The sludge showed cracking tendencies in 2 days and was ready for removal in 14 days, in contrast with a normal period of 30 days. Bryan (5) reports that the quality of the sludge was not affected by the addition of substance F to the digesters, but that the volume of sludge after digestion was reduced by more than 50 per cent. At another plant, substance C was added to sludge being dried to see if the additive would make the sludge easier to grind. There was no apparent improvement in the dosed portions over the normal sludge.

8. Aerobic Stabilization

One of the committee members undertook a laboratory study to determine the effect of additive B on the rate of aerobic oxidation of a mixture of domestic sewage and high-protein industrial waste. The rate of oxidation was observed by the use of War-

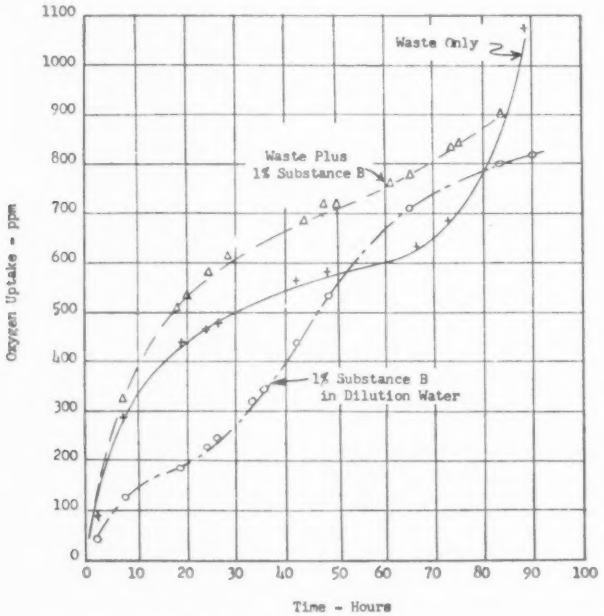

FIGURE 5.—Oxygen uptake studies on sewage plus industrial waste with and without substance B (Warburg respirometers, at 20° C.) (from Sanitary Engineering Research Staff, University of California).

burg respirometers. Figure 5 presents typical results of a series of oxygen uptake curves, reporting the waste alone as a control, a 1 per cent solution of B in "Standard Methods" (6) dilution water, and a mixture of the waste and 1 per cent of B. The use of substance B did not increase the rate of oxygen uptake or stabilization of the waste; in fact, it served only to increase the total oxygen demand of the mixture.

Reactions of Operators

It is interesting to note the responses to the question: "Do you plan to continue using the substance?" Twelve operators replied with an unqualified "No"; one stated: "No, unless a duly recognized competent authority can show that there is a definite benefit"; and one wrote, "Not at present—too costly and not enough conclusive results obtained to date." Only one operator gave an affirmative reply, but one other wishes to continue experimentation if his budget will allow a plant-scale test.

Conclusions

It is difficult for the Committee to draw many firm conclusions from the information gathered by this survey. The following tentative observations are advanced until further reliable experimental results are available to confirm or disprove them:

1. The new biocatalytic additives apparently contain numerous enzymes of the types which are capable of assisting or promoting biochemical decomposition, provided that they are not already present in the process.

2. These same enzymes are normally present in waste treatment processes in concentrations far greater than the recommended dosages of additives would provide, inasmuch as the enzymes are produced by the bacteria indigenous to the processes. Hence, the addition of biocatalytic substances in properly designed and operated plants will produce no benefits.

3. Additional enzymes are not indicated for collecting sewers or pumping stations as a means of reducing odors or H_2S formation. This purpose can be accomplished best by adequate aeration or by bactericidal agents.

4. The majority of reliable evidence indicates that biocatalytic additives will not increase gas production, improve pH, or alter the alkalinity and volatile acids in the digesters, nor will they change the quality of the supernatant liquor.

5. It is possible that the enzymes in these substances may exert beneficial action on scum blankets or clogged grease, especially if the normal enzymes in the waste treatment processes do not have access to the scum or grease. Further research in this respect is needed.

6. There is also a possibility that biocatalytic additives may improve the performance of percolation and oxidation ponds, especially during the initial operation of ponds used for seasonal organic industrial wastes; however this possibility should be investigated by reliable controlled experiments.

7. Many of the claims advertised by the promoters of these substances appear to be grossly overstated and misleading. Some of the claims, as quoted hereinbefore, border on the ridiculous and display an ignorance of the fundamental processes of waste treatment.

Recommendations

1. To the officers and Board of Directors of the California Sewage and Industrial Wastes Association, that the Association continue to survey the use of biocatalytic additives and to act as a clearing house for operating results and other information unless and until additional reliable research data become available.

2. To the members of the California Association:

(a) That they continue the excellent cooperation by contributing operating data and experiences to committees of the Association.

(b) That they take a cautious position toward the use of these substances, pending further proof of their efficacy.

(c) That no biocatalytic additive be purchased until after it has performed as claimed, in accordance with a written guarantee.

3. To the promotors of biocatalytic additives:

(a) That advertising literature be rewritten clearly and correctly so as not to misrepresent the merits of the product or to insult the intelligence of superintendents and operators.

(b) That the distributors deal directly with engineers, superintendents, or operators rather, than attempt to influence mayors, city managers, councilmen, or members of boards of public works, as has been reported to this committee.

(c) That an effort be made to obtain fundamental information and reliable data from controlled experiments to determine the effects of these substances on various unit processes in waste treatment. Such experiments should be conducted by recognized authorities in sewage works laboratories, universities, or research institutes, or by well-known consulting sanitary chemists or engineers. All work should be performed under a contract that allows the experimenter to publish or publicize his results regardless of the outcome.

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4. Heukelekian, H., and Berger, M., "Value of Culture and Enzyme Additions in Promoting Digestion." THIS JOURNAL, **25**, 11, 1259 (Nov., 1953).
5. Bryan, A. C., "How Enzymes Improved Sludge Digestion." *Pub. Works*, **83**, 12, 69 (1952).
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DETERMINATION OF PIPE CONDITION BY INSPECTION OF SEWERS *

By JOHN A. MCCOLLUM

Sewer Maintenance District Foreman, City of Los Angeles, Calif.

Determining the interior condition of sewer pipe in place by inspection or the use of tools is something most cities and counties generally have been remiss in until recently. That is true, also, of the City of Los Angeles, but during the past few years that city has been rapidly overcoming this deficiency, thanks to progressive top management and development of more modern and efficient equipment.

The first question which might arise in the minds of many is: "Why inspect pipe for deterioration?" Why not follow the easy pattern pursued in

* Presented at 1954 Annual Meeting, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

the past and wait until the street caves in, then start the usual confused planning as to how it can be repaired temporarily until the same thing happens at another location? Such tactics as these have no place in a well-planned, well-run maintenance organization such as is needed today.

The reasons for good inspection are many; some of them could be listed as follows:

As public employees the first duty of sewer maintenance personnel is to do everything possible to protect the health of their real bosses, the taxpayers. If, through pure negligence, lines are permitted to reach such a condition that sewage is exfiltrated or that lines collapse and streets become contaminated, they are aiding the spread of disease and causing undue nuisance. When such conditions exist the individual responsible is not doing a job that justifies the public's trust.

Sewer lines must be kept in operating condition at all times to protect the municipality from law suits. The time has passed when responsibility for damage done to private property due to collapsed or broken lines can be simply shrugged off. In the past few years there have been several court rulings that a municipality is responsible for damage caused by stoppages, broken lines, etc.

In a trial recently held in the City of Los Angeles, a property owner sued the city for damages caused by a rock entering the line and causing stoppage. During the course of testimony the judge asked a witness for the City of Los Angeles if he had any idea how the rock got into the sewer. The witness replied that children remove manhole covers and throw debris into the sewer; and also during rains citizens sometimes raise the cover to drain off excess water. The city lost its case. In the judge's ruling he said the city was negligent, due to the fact that it was known that such things happened and the lines should be inspected to prevent stoppages. There is a possibility that if a street caves in and private property is damaged the city might be held negligent, because it is known that pipelines deteriorate and provision should be made for new ones to be constructed to replace those in dangerous condition.

In order for the Design Division to have plans drawn up well in advance for replacement of lines, they must be informed as to the deterioration of any line. If this is not done they cannot be expected to draw plans, arrange for money, let the contract, and execute many other details on short notice. Unless maintenance can work in close harmony with design it is the public that will suffer. The matter of economy also plays a large part in maintenance.

Before any actual inspection can effectively be made, trained personnel should be on hand in sufficient number the insure the safety of all concerned. All municipalities should have men trained in sewer maintenance work. Regardless of the size, a small, well-trained crew will be much more efficient than a large one that devotes only a small part of its time to preventive maintenance. If a larger crew is needed occasionally, there will be a sufficiently trained group to carry on the work to a successful conclusion. Men joining an inspection crew for the first time should be thoroughly briefed as to the dangers of the work and what part they are expected to play. This can be done either by a short in-service training course or by instruction from the foreman. Members of an inspection crew must function as a team if maximum results are to be obtained. Inspection methods probably vary greatly in different places, but as long as results are accomplished and a high level of safety is maintained the procedure is not too important.

In the City of Los Angeles most inspections are made early in the

morning, when flow is at a minimum. Equipment is assembled at the end of the previous day and includes such items as blowers, lights, safety belts, boots, etc. For ventilation in small lines portable blowers of 1,600-c.f.m. capacity are used; in the larger lines, portable blowers of 7,500-c.f.m. capacity, two of which are available if needed. These blowers are of the suction type.

After the blowers are properly installed and a man is stationed at each one so he may sound alarm in case of mechanical failure, the crew is ready for actual inspection. When the inspector has put on his safety belt and entered the manhole he is ready to begin. While he is descending it is a good idea to probe the brickwork and mortar in the manhole. For this probing, the author uses a prospector's pick, but any sharp instrument can be used. If the manhole is soft, it is a good indication that the pipe also may be deteriorating.

After the bottom of the manhole is reached the inspector is ready for light to start his inspection. If the sun is shining the use of mirrors is one of the best ways to get light up the line. In pipes up to 12 in. in diameter accurate sighting is possible for a distance of 75 ft. In this distance one may see if the alignment is good and if there are any obstructions in the line. Here, again, the prospector's pick is used as far in as possible to determine if the walls are soft. Also, with Barnhill rods a scraper can be used on the sides of the pipe to determine the degree of softness. If the pipe is not in good alignment that condition should be noted and a picture taken, if possible.

In larger lines accurate sighting is estimated to be practical up to 100 ft. by the use of mirrors or a powerful spotlight. If inspection is made each way from the manhole a good idea of the condition of the pipe can be obtained. After the first person has completed his inspection another should be made by a qualified person. This should be done before any notes are compared. After these individual inspections have been completed, notes should be compared and a single conclusion arrived at. Should the two inspectors fail to reach an agreement, a third inspection may be necessary. However, this is unusual.

It is possible to walk through many of the larger lines at low flow. In these cases very detailed inspections can be made.

The age of the pipe has little bearing as to when deterioration will start. In Los Angeles there have been lines that had to be replaced after 10 years of service. On the other hand, recent inspection of a concrete line installed in the 1880's showed it to be in almost perfect condition; the alignment was good and the pipe was still very hard.

Small lines that are constructed on a curve present a major problem when it comes to inspection. It is possible to see 20 or 25 ft. in most lines, and if these are inspected thoroughly a good idea can be obtained as to the degree of softness. A ball or corkscrew hook could be used to determine if the pipe has collapsed.

Records should be kept or inspections will be useless. Written reports with attached photos should be on file. Inspections should be made at regular intervals and compared with previous reports. In this manner, it would be possible to determine the rate of deterioration and forecast well in advance when replacement is needed.

The need for accurate, intelligent inspection of pipe is great and must be given a permanent place in the preventive maintenance program if it is to be a success. Sewer maintenance as a precautionary measure is just beginning to come into its proper place. The aim must be to keep the sewer lines in such good condition that all sewage entering them may flow without loss to plants where it may be treated.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

1953 Annual Report of Greece, N. Y., Sewage Treatment Plant *

By Francis J. Cramer, *Superintendent*

As in 1952, most of 1953 was occupied with plant research directed toward increasing the efficiency of the plant. By the beginning of 1953 it had been discovered that variation of the air rate had little effect on plant results, but that by cutting out one final tank an improvement of about 10 per cent was realized. Addition of air to the influent and the first aeration tanks, coupled with series rather that paralled operation of the final settling tanks, makes it possible to handle adequately the 1.5-m.g.d. flow experienced during mid-day in a plant designed for 1.0-m.g.d. flow.

The plant has been overloaded throughout the year, particularly on Mondays and Saturdays (wash days). During March and April the plant was continually being upset, due to infiltration. Experimentation during the year involved different rates of return, methods of wasting activated sludge,

* For last previous extract see This Journal, **24**, 1, 101 (Jan., 1952).

TABLE I.—Summary of 1953 Operating Data, Greece, N. Y., Sewage Treatment Plant

Item	Average
Estimated population served	18,900
Population equivalent	14,130
Sewage flow (m.g.d.)	1.11
Sewage flow (g.p.c.d.)	60.7
Grit (cu. ft./m.g.)	5.67
Sludge (cu. ft./m.g.)	446
Scum (cu. ft./m.g.)	3.5
Settleable solids:	
Influent (ml./l.)	6.4
Effluent (ml./l.)	0.7
Suspended solids (p.p.m.):	
Raw sewage	219
Final effluent	51
Reduction (%)	75.8
B.O.D., 5-day (p.p.m.):	
Raw sewage	258
Final effluent	48
Reduction (%)	81.3
Primary sludge:	
Dry solids (%)	6.4
Vol. solids (%)	66.3
Activated sludge:	
Susp. sol., mixed liquor (p.p.m.)	744
Return sludge ratio (%)	29.8
Aeration period (hr.)	7.0
Susp. sol., return sludge (p.p.m.)	9,790
Sludge index, Mohlman	72
Chlorine:	
Used (lb./m.g.)	34
Residual (p.p.m.)	0.49
Vac. filter and incin. oper.:	
Lime (%)	11.9
Ferric chloride (%)	7.3
Time (hr./mo.)	342
Wet cake (lb./mo.)	283,500
Cake solids (%)	27.4
Equiv. dry solids:	
Lb. per mo.	79,150
Lb. per m.g.	2,365
Lb. per sq. ft. per hr.	2.55
Cost of operation ($):	
Total	65,947.78
Per m.g.	162.50
Per capita	3.48

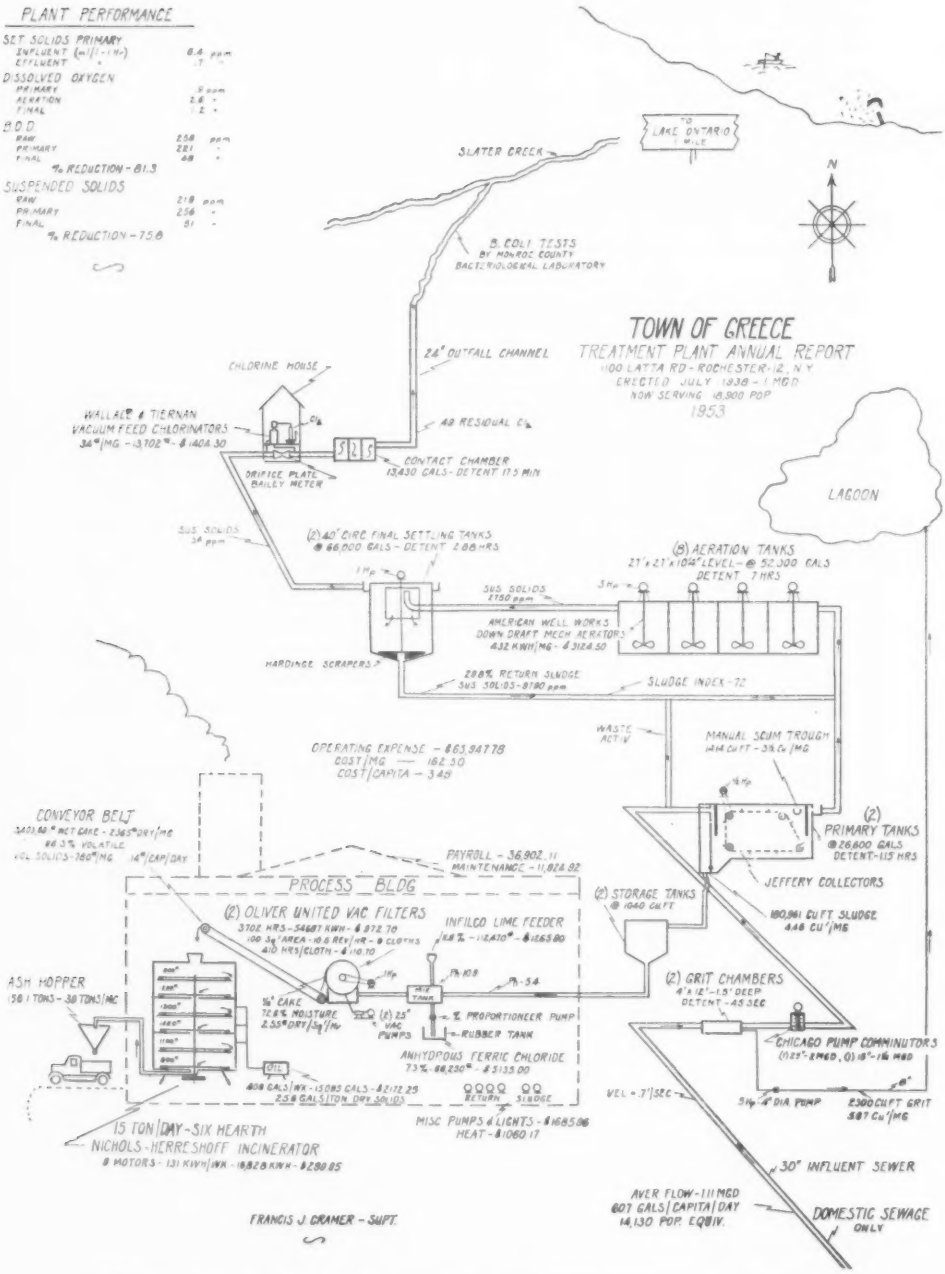

PLANT PERFORMANCE
SET. SOLIDS PRIMARY
INFLUENT (ml/l-1 Hr) 6.4 ppm
EFFLUENT " 1 "
DISSOLVED OXYGEN
PRIMARY 0 ppm
AERATION 2.6 "
FINAL 1.2 "
B.O.D.
RAW 258 ppm
PRIMARY 221 "
FINAL 68 "
% REDUCTION - 81.3
SUSPENDED SOLIDS
RAW 218 ppm
PRIMARY 256 "
FINAL 51 "
% REDUCTION - 75.8
TO LAKE ONTARIO 1 MILE
SLATER CREEK
N
B. COLI TESTS BY MONROE COUNTY BACTERIOLOGICAL LABORATORY
TOWN OF GREECE
TREATMENT PLANT ANNUAL REPORT
1100 LATTA RD - ROCHESTER-12, N.Y.
ERECTED JULY 1938 - 1 MGD
NOW SERVING 16,900 POP.
1953
CHLORINE HOUSE
24" OUTFALL CHANNEL
WALLACE & TIERNAN VACUUM FEED CHLORINATORS
34 #/MG - 13,702 #'s - @ 1.40/A.30
.48 RESIDUAL Cl2
CONTACT CHAMBER 13,430 CALS - DETENT 17.5 MIN
ORIFICE PLATE BAILEY METER
LAGOON
SUS. SOLIDS 34 ppm
(2) 40' CIRC. FINAL SETTLING TANKS @ 66,000 GALS - DETENT 2.08 HRS.
(8) AERATION TANKS 21'x 27'x 10'4" LEVEL - @ 52,300 CALS DETENT 7 HRS
SUS. SOLIDS 1750 ppm
AMERICAN WELL WORKS DOWN DRAFT MECH AERATORS 432 KWH/MG - @ 3.12/A.50
HARDINGE SCRAPERS
28.8% RETURN SLUDGE SUS. SOLIDS - 8780 ppm
SLUDGE INDEX - 72
WASTE ACT'V
MANUAL SCUM TROUGH 144 CU.FT - 3% Cu/MG
OPERATING EXPENSE - $63,947.78
COST/MG — 162.50
COST/CAPITA — 3.48
CONVEYOR BELT
3401.40 # WET CAKE - 2365 # DRY/HR.
66.3% VOLATILE
VOL. SOLIDS - 760 #/MG 14 #/CAP/DAY
PAYROLL - 36,902.11
MAINTENANCE - 11,824.92
PROCESS BLDG
(2) OLIVER UNITED VAC. FILTERS
3702 HRS - 54687 KWH - @ 872.70
100 Sq' AREA - 10.5 REV/HR - 8 CLOTHS
410 HRS/CLOTH - @ 110.70
INFILCO LIME FEEDER
18.8 % - 12,470 # - @ 165.80
(2) PRIMARY TANKS @ 26,600 GALS DETENT - 1.15 HRS
JEFFERY COLLECTORS
(2) STORAGE TANKS @ 1040 CU.FT
180,361 CU.FT SLUDGE 4.48 CU'/MG
(2) GRIT CHAMBERS 4' x 12'-1.5' DEEP DETENT - 45 SEC
ASH HOPPER
50 TONS - 30 TONS/HR
1/4" CAKE 72.6% MOISTURE 2.55 # DRY/Sq'/Hr
(2) 25" VAC. PUMPS
2" PROPORTIONEER PUMP
RUBBER TANK
ANHYDROUS FERRIC CHLORIDE
7.3% - 88,230 # - @ 3135.00
CHICAGO PUMP COMMINUTORS (1) 25"-2 MGD, (1) 18"-1.5 MGD
VEL. = 1.1'/SEC
5 H.P. 4" DIA. PUMP
2300 CU.FT. GRIT 5.87 Cu'/MG
408 CALS/WK - 15,085 CALS - @ 2.12.25
2.5 @ CALS/TON DRY SOLIDS
RETURN SLUDGE
MISC PUMPS & LIGHTS - @ 168.86
HEAT - @ 1060.17
15 TON/DAY - SIX HEARTH NICHOLS-HERRESHOFF INCINERATOR
8 MOTORS - 131 KWH/WK - 16,928 KWH - @ 280.85
30" INFLUENT SEWER
AVER. FLOW - 1.11 MGD
607 GALS/CAPITA/DAY
14,130 POP. EQUIV.
DOMESTIC SEWAGE ONLY
FRANCIS J. CRAMER - SUPT.

FIGURE 1.—Single schematic diagram showing plant processes, equipment, and average or total operating data for entire year is more easily understood by lay official than is usual written report.

methods of drawing sludge, methods of sludge collector operation, chlorination of raw sewage, and chlorination of return activated sludge.

Routing of the sewage through the aeration tanks was varied and air was introduced with diffusers to the raw sewage and the primary effluent.

Not all guesses were good ones, but the over-all B.O.D. removal was raised to 81.3 per cent from its 1952 value of 78.3 per cent and the suspended solids reduction was raised from 73.8 per cent (1952) to 75.8 per cent.

Besides the usual mimeographed annual report, an annual report was prepared in diagrammatic form (Figure 1). This type of report is much more concise, and yet more informative to and better understood by a lay official or taxpayer.

For the more technically trained, Table I summarizes the operating data for 1953.

Annual Report of the Green Bay (Wis.) Metropolitan Sewerage District for the Years Ended March 31, 1952 and March 31, 1953 *

By George W. Martin, *Chief Engineer and Superintendent*

Labor Distribution

The labor distribution schedule disclosed that of the total of 19,975 manhours of work performed in operating the treatment plant in 1951–52, plant operation required 37 per cent and plant repairs and maintenance required 11 per cent. Miscellaneous, plant laboratory, experimental laboratory, and janitor service each required from 6 to 8 per cent of the total time. The remainder was devoted to 29 different breakdown items.

Sewage Flow

An average of 12.12 m.g.d. of sewage was treated during 1951–2. This amounts to one-third more than was treated the previous year. In addition, a total of 1,251 m.g. was by-passed to the river through the storm-water pumping station. This was also one-third more than the corresponding flow for the previous year. Some of the increase is accountable by reason of a 15 per cent increase in precipitation above the previous year, the remainder being attributable to infiltration due to high ground-water levels caused by high lake levels.

In 1952–53 sewage flow decreased again to 11.37 m.g.d. and by-passed storm water amounted to only 1,013.7 m.g., due to lower precipitation and lower lake levels.

Oxidator Experiments

In 1953 the Oxidator experiment, set up two years previously, was terminated and it was concluded that the results obtained while operating under what were considered standard conditions for the District were not sufficiently promising to warrant installation of additional units.

Digestion

Digestion capacity is low and at times, especially during the canning season, it is impossible to obtain a clear supernatant liquor. This condition should be overcome as soon as the new 85-ft. diameter secondary digester now under construction is placed in service.

Gas production in 1952–3 was up to about 1.5 cu. ft. per capita per day. This is above expectations and probably is due to the load received from a packing plant and from recently installed household garbage grinders.

* For last previous extract see This Journal, **24**, 10, 1317 (Oct., 1952).

TABLE II.—Summary of 1951–2 and 1952–3 Operating Data, Green Bay (Wis.) Metropolitan Sewerage District

Item	Average 1951–2	1952–3
Rainfall (in.)	32.84	23.84
Tributary population, est.	65,000	65,000
Sewage flow (m.g.d.)	12.12	11.37
Storm water by-passed, tot. (m.g.)	1,251	1,014
Screenings (cu. ft./day)	13	10
Grit (cu. ft./day)	28	22
Raw sludge, total dry sol. (tons)	2,906.4	2,949.1
Dry solids (lb./day)	15,882	16,159
Vol. dry sol., total (tons)	1,871.5	2,024.8
Vol. dry sol. (lb./day)	10,227	11,095
Sludge gas (cu. ft. per day):		
Produced	83,309*	96,081*
Consumed	95,183*	102,262*
H_2S (gr./100 cu. ft.):		
Max.	110	56
Min.	4	18
Digested sludge withdrawn:		
Wet sludge, total (cu. yd.)	10,554	16,827
Moisture (%):		
Max.	94.1	97.0
Min.	85.4	82.8
Vol. matter (%):		
Max.	57.1	67.4
Min.	37.9	35.9
5-day B.O.D. (p.p.m.):		
Influent	169	219
Final effluent	126	158
Reduction (%)	25.0	27.9
Suspended solids (p.p.m.):		
Influent	209	251
Final effluent	105	124
Reduction (%)	49.8	50.6
Chlorine:		
Total used (lb.)†	78,430	59,975
Max. dosage (p.p.m.)	11.3	9.7
Electrical energy (kw.-hr.):		
Produced by plant, total	1,063,964	1,090,394
Consumed, total	1,360,976	1,310,582
Operating costs ($):		
Total	68,875	75,372
Per m.g.	15.53	18.16

* Metering error. † Four months.

Secondary Plant.

Chlorination was not up to requirements due to high flows and low chlorine feed capacity. This condition will be corrected when the proposed secondary treatment plant is built. Considerable work has been done on planning for this expansion, which is expected to be detailed and under construction in 1954.

Table II summarizes operating data for 1951–2 and 1952–3.

SOME FACTORS INVOLVED IN LOCATING SEWERS

By Cedric Webster

Superintendent, Menlo Park Sanitary District, Menlo Park, Calif.

Editor's Note—Mr. Webster's comments were engendered by a request in the April 1954 issue of This Journal (page 571) for information regarding the relative merits of installing sanitary sewers in the streets rather than on the rear property lines when there are no alleys available.

Much has been heard, but little written, on the question of where to place sewers with respect to the property served. And despite the seemingly thorough discussion of the matter, the same question keeps arising from time to time. Perhaps, therefore, some comments on the experience of the Menlo Park (Calif.) Sanitary District in this respect may be of interest to others.

The District Board, it should be explained, has adopted a hard and fast rule prohibiting the locating of sewers on easements. The only exceptions permitted are in those cases where topographic conditions make it impossible to do otherwise. There are some sound reasons behind this rule.

Experience has shown that sewers running through back yards—or along rear property lines not on alleys—require far more maintenance than those located in the public street. This is principally due to the sewer in the street being subject to less root trouble, and also that the street sewer manholes are visible at all times. Finding a manhole on the public street is always an easy matter, but finding one located in someone's back yard can be a woefully discouraging business. There has been at least one instance where only the threat of a court injunction was sufficient to stop an irate homeowner from ordering the maintenance crew from her premises.

Not to be overlooked are the physical difficulties of dragging in equipment through gates and over fences. Also not to be ignored is the difficulty of using the equipment when surrounded by fences, trees, shrubs, etc.

Another factor to be considered is the sometimes quite voluble, if not violent, aversion manifested by some homeowners and their dogs when the maintenace crew starts trampling through flower beds. Many people simply do not understand the rights conveyed in a public utility easement.

The fact that the cost to a subdivider may be greater when he is required to put his sewers in the streets than it would be to put them in the rear of lots is to be regretted. It should, however, have no bearing whatever on the decision of the sewer authority, whose responsibility is solely to the public as a whole and not to any individual. As the old proverb says: "It's not the first cost that counts, it's the upkeep!" —and the upkeep of the sewer system is what keeps up the tax rate.

TIPS AND QUIPS

Michigan Fish Killings

Of seven fish killings reported to the Michigan Water Resources Commission during the second quarter of 1954, four were caused by industrial waste, none by municipal sewage. Cyanide accounted for mortality in Rouge River, Lake Drain, and Brent Run, Genesee County. Potato processing wastes caused deaths in Big Swamp Drain and Jones Lake, Genesee County.

Disposal of ground water pumped to dewater Reed City's new sewage treatment plant site killed fish in the Hersey River. These waters were found to contain phenol, attributed to ponding of wastes from a wood creosoting plant which formerly occupied the site.

Sewer Rod Guide Jack

A fast-acting jack to hold securely a cable-type sewer rod guide in place in a manhole is easily made from a standard automobile bumper jack. According to C. Webster, Superintendent of the Menlo Park (Calif.) Sanitary District, the shop-made jack has several advantages over the turnbuckle type supplied by the rod equipment manufacturer.

Figure 1 shows how the base of the jack is bent to fit the rod guide, as well as how the jack is used to hold the guide in place. If desired, the jack base may be lined with rubber to prevent slippage between that piece and the rod guide.

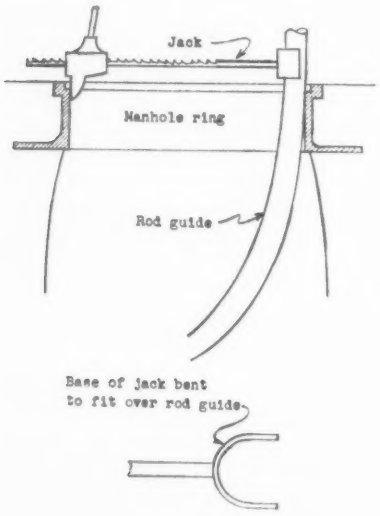


FIGURE 1.

Surefooted Sole Tread

The latest in safety footwear for use in wet or oily locations is a surefooted neoprene rubber sole tread of patented design providing excellent traction through its squeegee gripping action. Originally developed for Navy use on wet and oily decks, the sole is now being applied to a variety of industrial boots, shoes and overshoes by several footwear manufacturers. Known as the "Tri-Vac" sole, the design consists of multiple concentric circles molded in the rubber to give a non-skid suction grip.

Easily-Made Sewer Plug

Extremely useful and inexpensive sewer plugs for sewers of 10-in. or larger diameter can be shop-made from material usually on hand and standard pneumatic tire inner tubes of appropriate sizes. Figure 2 shows the details of such a plug as used by the Menlo Park (Calif.) Sanitary District. The tube should be partially inflated to determine the size of the spacer holding the plywood discs apart. The proper

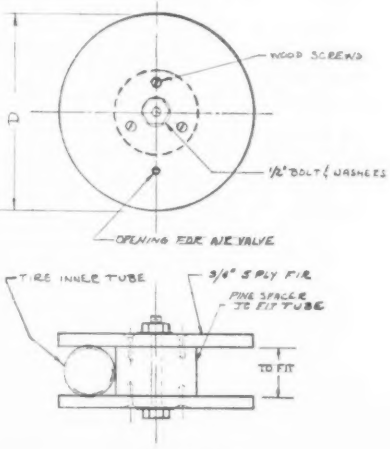


FIGURE 2.

diameters of the plywood discs for various sizes of pipe are as follows:

Sewer Diam. (in.)	D (in.)
10	$9\frac{11}{16}$
12	$11\frac{5}{8}$
15	$14\frac{5}{8}$
18	$17\frac{9}{16}$
21	$20\frac{1}{2}$
24	$23\frac{7}{16}$

After the plug has been inserted in the pipe, the tube is inflated with a standard automobile or bicycle hand pump. A further refinement is possible by extending the valve stem with a rubber hose to the street surface so the plug can be inflated and deflated from that level.

Safety Note

Around machinery, metal safeguards are good, mental safeguards are better, but both in combination are best!

Skin Protection

A new barrier hand cream for industrial use against contact dermatitis and sensitizing agents encountered on the job has been placed on the market. Known as "Kerodex," the protectant is claimed to have a "push-off" feature to save clean-up time and eliminate the need for harsh abrasives, solvents, or strong soaps in wash-up. According to the manufacturers, Ayerst Laboratories, Inc., 22 East 40th St., New York City, the cream is particularly effective against contraction of poison ivy.

Spontaneous Reaction

Something was known to be amiss when the low-pressure sediment strainer on the gas line of No. 2 digester at Cincinnati's Little Miami plant recently was reported "hot" to the touch. According to Superintendent D. P. Backmeyer, in the plant's monthly news bulletin, the adjoining piping showed no evidence of heat above room temperature.

When the strainer was opened it was found that a light coating of iron sulfide inside it had ignited. Apparently some air had been admitted to the digester floating cover dome when a new diaphragm was installed on the pressure relief valve just a few minutes before the hot strainer was noticed.

Moral: Be extremely careful of spontaneous ignition in such places as gas lines and gas equipment where iron sulfide deposits may come in contact with oxygen, especially when opened to the air.

MAKE YOUR HOTEL RESERVATIONS FOR THE CINCINNATI MEETING

Requests for room reservations for the Federation's 27th Annual Meeting, to be held at Cincinnati, Ohio, October 11–14, should be addressed directly to the Netherland Plaza Hotel, Cincinnati, Ohio (see page 1188).

WRITE NOW FOR YOUR RESERVATIONS!

Federation Affairs

TWENTY-SEVENTH ANNUAL MEETING PREVIEW

Netherland Plaza Hotel, Cincinnati, Ohio, October 11–14, 1954

★

IN CONJUNCTION WITH

THE OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

★

THE OFFICIAL PROGRAM

SUNDAY, OCTOBER 10

Afternoon

Early Registration—Fourth Floor Foyer
Inspection of Exhibits—North and South Exhibit Halls

MONDAY, OCTOBER 11

Morning

Registration—Fourth Floor Foyer
Inspection of Exhibits—North and South Exhibit Halls
Twenty-Seventh Annual Meeting Called to Order—Hall of Mirrors
President L. J. Fontenelli
Invocation—Dr. Melvin R. Campbell
Welcome to Cincinnati
T. J. Montgomery, City Engineer, Cincinnati, Ohio
Reports of Federation Officers
Pollution Control in the Ohio Valley
Hudson Biery, Ohio Commissioner, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio
Solution of Cincinnati's Sewage Problems
Arthur D. Caster, Sewage Disposal Engineer, City of Cincinnati, Ohio

Afternoon

Moving Picture—Clean Waters (1954 Edition)
Introduced by H. R. Walrath, Manager, Contractor and Construction Industries Sales, General Electric Co., Schenectady, N. Y.
Evaluating the Variables in Vacuum Filtration
Arnold J. Beck, E. N. Sakellariou, and M. Krup, The Sanitary District of Chicago, Ill.
Discussion: Robert D. Bargman, Assistant Chief Engineer, Sewage Treatment Plant, Los Angeles, Calif.
Activated Sludge Thickening by Centrifuging
R. E. Bragstad, City Engineer, and Leland Bradney, City Chemist, Sioux Falls, S. Dak.

Discussion: L. S. Kraus, Chemist, Greater Peoria Sanitary District, Peoria, Ill.

Oxygen Absorption Efficiency Studies

A. A. Kalinske, Director of Development, Infilco, Inc., Tucson, Ariz.

Discussion: Henry R. King, Senior Civil Engineer, The Sanitary District of Chicago, Ill.

Loading to Failure of a Pilot High-Rate Digester

Wilbur N. Torpey, Senior Civil Engineer, Dept. of Public Works, New York, N. Y.

Discussion: Harry E. Schlenz, President, Pacific Flush Tank Co., Chicago, Ill.

Evening

FAMILY NIGHT ENTERTAINMENT—Pavillon Caprice

TUESDAY, OCTOBER 12

Morning

Moving Picture—Diffusion of Effluents Discharged to Puget Sound

Introduced by R. G. Tyler, Professor of Sanitary Engineering, University of Washington, Seattle, Wash.

Treatment of Sewage Plant Effluent for Industrial Re-Use

R. J. Keating and V. J. Calise, Graver Water Conditioning Co., New York, N. Y.

Electric Power Reliability Requirements in Sewage Works

E. O. Potthoff and N. L. Hadley, Water and Sewage Application Engineers, General Electric Co., Schenectady, N. Y.

Effects of Thermal Loadings on Stream Sanitation Criteria

Joseph R. Clark, E. I. du Pont de Nemours & Co., Wilmington, Del.; and Sheppard T. Powell and E. L. Knoedler, Consulting Engineer, Baltimore, Md.

Discussion: Lloyd R. Setter, Assistant Chief, Physics and Chemistry Section, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

Increased Income for Inventors

Anthony J. Fischer, Assistant Manager, Development Department, The Dorr Co., Stamford, Conn.

Noon

FEDERATION LUNCHEON—Pavillon Caprice

The General Economic Outlook

Dexter M. Keezer, Director of Economics Staff, *Business Week*, and Vice-President, McGraw-Hill Publishing Co., New York, N. Y.

Afternoon

Moving Picture—Sewer Maintenance Practice in Mexico City

Infiltration Specifications and Tests

Charles R. Velzy, Consulting Engineer, New York, N. Y.; and J. M. Sprague, Clay Products Association, New York, N. Y.

Discussion: C. Gordon Gaither, Howard K. Bell, Consulting Engineers, Lexington, Ky.

Safety in Sewage and Waste Treatment—Demonstration

L. W. Van Kleeck, State Department of Health, Hartford, Conn., with cooperation of Mine Safety Appliances Co.

WEDNESDAY, OCTOBER 13

Morning

Anaerobic Contact Process Applied to Packinghouse Wastes

George J. Schroepfer, Professor of Sanitary Engineering, University of Minnesota; W. J. Fullen, Chemist, George A. Hormel & Company, Austin, Minn.; A. S. Johnson and N. R. Ziemke, Instructors in Civil Engineering, University of Minnesota; and J. J. Anderson, Project Engineer, American Meat Institute, Minneapolis, Minn.

Biological Properties and Behaviors of Cyanogenic Wastes

Charles E. Renn, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.

Discussion: C. M. Tarzwell, Chief, Biology Section, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

Waste Pickle Liquor Disposal by Controlled Oxidation and Continuous Lime Treatment

L. W. Heise and Milton Johnson, A. O. Smith Corp., Milwaukee, Wis.

Discussion: Richard D. Hoak, Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Application of Biological Treatment Processes to Industrial Wastes

R. F. Weston, Sanitary Engineer, Atlantic Refining Co., Philadelphia, Pa.; and W. W. Eckenfelder, Jr., Weston, Eckenfelder and Hood, Inc., Ridgewood, N. J.

Discussion: B. W. Dickerson, Engineering Department, Hercules Powder Co., Wilmington, Del.

Afternoon

Inspection Trip

Little Miami Sewage Treatment Plant and the Robert A. Taft Sanitary Engineering Center

Evening

ANNUAL FEDERATION DINNER—Hall of Mirrors
DANCE—Pavillon Caprice

THURSDAY, OCTOBER 14

Morning—Concurrent Sessions

THE OPERATORS' FORUM

C. C. Larson, Leader

Salary Schedules and Classifications

T. C. Schaetzle, Engineer in Charge, Sewage Treatment Works, Akron, Ohio

Biocatalysts in Sewage Treatment

INDUSTRIAL WASTES FORUM

Kenneth S. Watson, Leader

Industrial Waste Specifications in Municipal Ordinances Disposal to Public Sewers *vs.* Separate Treatment

Afternoon

Process Wastes from Petrochemicals Manufacture

O. C. Thompson, Sanitary Engineer, Veterans Administration, Arlington, Va.; and George F. Jenkins, Engineering Department, Carbide and Carbon Chemicals Co., South Charleston, W. Va.

Discussion: E. B. Showell, Consulting Engineer, Chadds Ford, Pa.

Ion Exchange Units for Treatment of Electroplating Wastes

T. J. Fadgen, Chief Chemist and Metallurgist, Ternstedt Division, General Motors Corp., Trenton, N. J.

Treatment and Recovery of Soluble Oils

Clark W. Hathaway, Metallurgical Department, Chevrolet-Detroit Forge, Detroit, Mich.

Discussion: T. R. Haseltine, The Chester Engineers, Pittsburgh, Pa.

Dephenolizing of Wastes by Continuous Countercurrent Solvent Extraction

H. R. Kaiser, Vice-President, Podbielniak Corp., Chicago, Ill.

TECHNICAL PROGRAM COMMENTS

The Program Committee, under the chairmanship of F. W. Gilcreas, has again developed a technical program with appeal to the many diverse interests of Federation activity. Each member and guest attending will find interest in some part of the meeting program.

To provide more technical papers, particularly in the industrial wastes field, as well as provide a complete afternoon for an inspection trip to two of the Cincinnati area's most interesting sanitation facilities, the Operators' Forum and Industrial Wastes Forum will be held concurrently on Thursday morning, as they were until 1952. To further enlarge the program, an entire extra session of industrial wastes papers has been added on Thursday afternoon.

All technical sessions will be held in the Hall of Mirrors, Netherland Plaza Hotel. One of the concurrent forum sessions, however, will be held in the nearby Pavillon Caprice.

SOCIAL FUNCTIONS

An informal Family Night Entertainment on Monday evening will provide a strictly home-talent show in South Seas theme and setting, offered by members of the staff of the Division of Sanitary Engineering, Illinois Department of Public Health. Here is a good opportunity to get acquainted, relax, and have fun among friends.

The Annual Federation Luncheon, to be held Tuesday noon in the Pavillon Caprice, as usual will be a highlight event of the meeting. The featured speaker, Dexter M. Keezer, is Director of Economics Staff, *Business Week*, and Vice-President of the McGraw-Hill Publishing Company. He will speak on the general economic outlook, with particular reference to the public works aspects.

No meal or entertainment events are scheduled for Tuesday evening, which is thus left open for dining or entertainment according to individual choice. Local Host Committee arrangements are being made to provide this type of information for all who seek it.

The focal point of the meeting will be the perennially popular Awards Dinner on Wednesday evening. To be held in the beautiful Hall of Mirrors, this event will feature the presentation of the annual Federation awards and honors. Dress will be optional, with dancing following in the Pavillon Caprice.

The Business Luncheon of the Ohio Conference on Sewage and Industrial Wastes Treatment is scheduled for 12:00 Noon on Wednesday, October 13, in the Pavillon Caprice, Netherland Plaza Hotel. Guests will be welcome; tickets are priced at $3.00.

A dinner meeting of the Loyal Order of the Boar also is scheduled at the Netherland Plaza Hotel at 6:00 P.M. on Tuesday, October 12. Arrangements are in charge of W. A. Hardenbergh, J. J. Gilbert, and Alden E. Stilson; tickets are priced at $5.00.

LADIES' ENTERTAINMENT

Special entertainment for the ladies will be centered around the local sightseeing attractions of this famous old Ohio River rail and water transportation center.

These events will be in addition to those scheduled for Monday and Wednesday evenings, as outlined under "Social Functions."

On Monday afternoon the Ohio Conference will be host for a Get-Acquainted Tea and Fashion Show. An added attraction will be a demonstration of luggage packing by a service representative of a world-wide airline.

Tuesday afternoon will be occupied by a bus trip to the Procter and Gamble plant at Ivorydale to see how soaps and Crisco are made and packaged. Several points of interest will be seen on the return trip.

Stops at the famous Rookwood Pottery and the Eden Park Conservatory of Flowers will feature a bus trip on Wednesday morning. Also included will be a drive on the scenic Columbia Parkway along the river.

INSPECTION TRIP

The inspection trip on Wednesday afternoon will feature visits to both the new Robert A. Taft Sanitary Engineering Center of the USPHS and to Cincinnati's new Little Miami sewage treatment plant. Located near each other about six miles from the center of the city, these two installations should be of considerable interest to all those engaged in the Federation's various fields of activity.

The Sanitary Engineering Center comprises a new $4,000,000 building housing the sanitary engineering research facilities of the USPHS. This activity, covering many of the related fields of sewage treatment, industrial wastes control and treatment, analytical methods, and stream pollution testing and rectification, replaces the former Environmental Health Center.

The 29-m.g.d. Little Miami plant, in operation only a short time, is the first of four plants planned to serve the Cincinnati metropolitan area. This feature of the city's $47,000,000 sewage treatment construction program is of particular interest because it is at present the largest treatment plant on the main stem of the Ohio River. A second plant, to handle 120 m.g.d., is currently under construction.

MANUFACTURERS' EXHIBIT

New and improved equipment and supplies in the wastes treatment field will feature the displays arranged by the 35 members of the Water and Sewage Works Manufacturers' Association who will exhibit at the meeting. All avail-

able exhibit space had been allocated by July 14. In addition to being able to see the latest in equipment and supplies, first-hand technical data on the various company products and services will be available through the medium of well-informed company representatives.

The following companies have scheduled representation in the exhibit:

ACF Industries, Inc.
Airkem, Inc.
American City Magazine
American Well Works
Armco Drainage & Metal Products, Inc.
B–I–F Industries, Inc.
Ralph B. Carter Company
Chain Belt Company
Chicago Pump Company
Combustion Engineering, Inc.
Dorr Company, Inc.
Engineering News-Record
Fairbanks, Morse & Company
Fischer & Porter Company
Flexible Sales Corp.
Hardinge Company, Inc.
Homestead Valve Manufacturing Company
Inertol Company, Inc.
Infilco Inc.
Jeffrey Manufacturing Company
Johns-Manville Sales Corp.
Komline-Sanderson Engineering Corp.
Lakeside Engineering Corp.
Link-Belt Company
Lock Joint Pipe Company
Mine Safety Appliances Company
Pacific Flush Tank Company
Price Brothers Company
Public Works Magazine
Simplex Valve & Meter Company
Walker Process Equipment, Inc.
Wallace & Tiernan, Inc.
Wastes Engineering
Water & Sewage Works
Yeomans Brothers Company

REGISTRATION INFORMATION

Registration facilities will be located in the Fourth Floor Foyer at the entrance to the exhibit area. The desk will be open for early arrivals on Sunday, October 10, until 5 P.M. On Monday, Tuesday, and Wednesday the desk will be open from 8:30 A.M. to 5 P.M., and on Thursday from 8:30 A.M. to noon.

Men's registration at $12.00 will include technical session privileges, the Family Night Entertainment on Monday, and the Annual Awards Dinner and Dance on Wednesday evening. In separate tickets the registration fee (required for attendance of technical sessions) is $6.00 and the Wednesday dinner and dance combination also is $6.00.

Separate tickets will be sold for the Federation Luncheon on Tuesday at $3.00, and for the Wednesday afternoon Inspection Trip at $1.00.

Ladies' registration at $12.00 includes the Monday evening entertainment, the Wednesday evening Dinner and Dance, and all special events in the ladies' program.

Early registration—before 5 P.M. on Sunday—will avoid the rush on Monday morning and also allow a leisurely visit to the manufacturers' exhibit.

HOTEL ARRANGEMENTS

A liberal allocation of rooms has been made by the Netherland Plaza Hotel for assignment to Federation members and guests. Reservations should be made early, however, to assure accommodations in the headquarters hotel. When all available rooms in the Netherland Plaza are committed, reservation requests will be referred to the nearby Terrace Plaza and to other first-class hotels.

Requests for reservations may be made on the forms provided with the advance notice of the meeting sent in June to all *Journal* subscribers, or directly to the Netherland Plaza Hotel, Cincinnati, Ohio.

LOCAL ARRANGEMENTS COMMITTEE

The Local Arrangements Committee, under the general chairmanship of Arthur D. Caster, Principal Engineer in the Cincinnati Department of Public Works, is composed of the chairmen of the following sub-committees:

Registration Committee: W. E. Conrad, chairman; C. E. Fisher, R. K. Horton, H. A. Lurie, J. E. Kinney, J. E. Richards, O. N. Cochran, and J. Frook.

Finance Committee: J. Van Gelder, chairman; J. Crane, and D. M. Taylor.

Entertainment Committee: T. Scott, chairman; J. C. Bumstead, and F. Farr, Jr.

Ladies Entertainment Committee: C. H. Allen, chairman; Mrs. A. D. Caster, Mrs. C. H. Allen, Mrs. A. B. Backherms, Mrs. D. P. Backmeyer, Mrs. J. C. Bumstead, Mrs. E. J. Cleary, Mrs. J. Crane, Mrs. F. H. Dobb, Mrs. W. G. Hamlin, Mrs. R. K. Horton, Mrs. J. E. Kinney, Mrs. H. P. Kramer, Mrs. H. A. Lurie, Mrs. H. H. Mace, Mrs. V. G. MacKenzie, Mrs. T. Scott, and Mrs. D. M. Taylor.

Local Host Committee: A. B. Backherms, chairman; P. Haney, W. A. Moore, S. J. Ludzack, F. M. Middleton, R. C. Kroner, R. G. Snapp, R. R. Weber, and D. Enright.

Hotel Arrangements Committee: H. H. Mace, chairman; F. H. Dobb, S. W. Shafer, E. P. Baker, and G. Kirch.

Inspection Trip Committee: H. P. Kramer and D. P. Backmeyer, co-chairmen; S. R. Weibel, A. E. Schwer, Jr., and H. C. Broge.

Publicity (Local) Committee: E. J. Cleary, chairman; and W. G. Hamlin.

DONALD P. SCHIESSWOHL JOINS STAFF

The recently created position of assistant to the Federation's Executive Secretary has been filled by the appointment of Donald P. Schiesswohl, effective August 16, 1954.

As a sanitary engineer with the Bureau of Sanitary Engineering, Florida State Board of Health, Mr. Schiesswohl's duties were primarily in the field of sewage and industrial wastes. In coming with the Federation headquarters staff he leaves the office of Secretary of the Florida Sewage and Industrial Wastes Association, which he held for the past three years.

He received the degree of Bachelor of Science in Civil Engineering from the Ohio State University in 1943 and the Master of Science degree in Sanitary Engineering from the University of Michigan in 1948. A registered professional engineer, he holds membership in the American Society of Civil Engineers and the Florida Engineering Society.

Mr. Schiesswohl will assist in the general executive administration of Federation affairs. He will also handle some Journal editorial duties, including the "Operators' Corner."

Reviews and Abstracts*

Reducing Phenol Wastes from Coke Plants. Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio. 36 pp. $1.00 (1953).

This manual in the ORSANCO industrial waste treatment series describes a variety of coke plant process changes and treatment methods which have proven practical in handling phenol waste problems. It also describes the sources, volumes, and concentrations of by-product coke wastes and methods for measuring phenols in industrial wastes.

H. P. Orland

A Submersible Photoelectric Absorptiometer. By L. J. Scragg, R. Briggs, and G. Knowles. *Jour. Scientific Instruments*, **31**, 75 (Mar., 1954).

The instrument described was developed to measure turbidity in rivers and comprises a lamp and a 20-element barrier-layer photocell which are lowered in cylinders fitted with windows. A second photocell mounted with the lamp compensates automatically for variations in its brightness. Cables run to a simple vacuum-tube voltmeter at the surface; power is from an accumulator and a dry battery. The range is from 0.01 to 100 per cent transmission, and readings can be made to a depth of 100 ft. The description includes simple methods of making cable entries and windows watertight although demountable. H. P. Orland

The Ecology of Alamitos Bay, California, with Special Reference to Pollution. By Donald J. Reish and Howard A. Winter. *Calif. Fish and Game*, **40**, 2, 105 (Apr., 1954).

In an extensive pollution survey of the local waters near San Diego, Calif., it was found that no conditions serious to fish and aquatic life exist in Alamitos Bay, although lumps of asphalt were observed at one station, near the oil fields, strong sulfide odor characterized two stations on a tributary arm, and a strong sulfide odor was noted at a station near a storm sewer outfall and above the tidal gates. No sludge beds were found in Alamitos Bay and there was no evidence of seepage of pollutants from the San Gabriel River into Alamitos Bay. The substratum of the Bay supports a rich and varied fauna, a knowledge of which should be of particular value in comparing this region with other Southern California harbors and bays that are affected by domestic and industrial waste discharges. H. P. Orland

The Results of Research on Citrus Processing Waste Disposal. By J. W. Wakefield. *Proc. Fla. Hort. Soc.*, **66**, 246 (1954).

The methods of treatment of citrus processing waste investigated included (a) high-rate trickling filter, (b) activated sludge, (c) spray irrigation, and (d) chemical flocculation with air flotation. The studies amply demonstrated that citrus waste can be treated without an unusually large capital outlay. Use of high-rate filters has been studied to the point where satisfactory results can be predicted with reasonably conservative loadings (0.239 lb. B.O.D. per cu. ft. per day).

The activated sludge process holds great promise but it is not possible to accurately predict the quantity of air needed or the type of secondary clarifier needed. It has been suggested that activated sludge followed by air flotation might be a good combination that would take advantage of the apparent lightness of the activated sludge floc.

In both trickling filters and activated sludge it is indicated that nitrogen and phosphorus additions will be required, but the costs should not be prohibitive.

The spray irrigation process is especially attractive for plants located near cheap

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

high dry land. However, a suitable cover crop that can withstand the low pH of citrus waste is needed. Automatic pH control will probably be necessary to prevent killing the cover crop during clean-up periods, but this same control also would be necessary with all the other methods.

Chemical flocculation-air flotation treatment of citrus waste to remove solids did not prove successful to any surprising degree, although about 100 p.p.m. of lime were used for flocculation.

H. P. ORLAND

Control of Acid Drainage from Coal Mines. Pennsylvania Sanitary Water Board, Harrisburg, Pa. 28 pp. (1952).

This booklet discusses the means of reducing the pollution of streams by coal mine drainage, mostly by prevention of acid production. The three acid-making elements (air, water, and sulfur-bearing materials) can be kept apart by (a) keeping the water out, (b) keeping the drainage moving, (c) segregating sulfuritic materials, and (d) neutralizing acid pools. Methods of accomplishing these objectives are discussed in detail. H. P. ORLAND

The Performance of Biological Filters in Johannesburg. By J. R. BAILLARD. *Pub. Health* (S. Africa), **17**, 367 (1953).

From data obtained during actual operation of all of the trickling filters at the various Johannesburg sewage treatment plants, it appears that, although vastly different sewages are treated at a number of different rates of flow, a common measure of the over-all loading and hence a measure of the performance of each group of filters may be found by use of an arbitrary "load unit." This unit is the product of strength (oxygen absorbed from permanganate in 4 hr.) and dosage (gallons per cubic yard per day).

Thus, for straightforward filtration on 6-ft. deep filters a loading in excess of about 10,000 load units (Table I) may be expected to give a poorly nitrated effluent with low stability.

On the other hand, dosing of filters with well-nitrated effluents, either from other units or by recirculation, is remarkably beneficial in treating to full nitrification and stability a greater volume of settled sewage than would otherwise be the case.

H. P. ORLAND

TABLE I.—Performance of Johannesburg Filters

Loading Group	Plant	Media Size (in.)	Settled Sewage Feed to Filters					Effl. Quality			Effl. after Sand Filtration		
			Dosing Rate (g.p.d. per cu. yd.)	Strength[2] (p.p.m.)	Chloride (p.p.m.)	B.O.D. (p.p.m.)	Load Units[3]	4-Hr. O/A (p.p.m.)	NO_3–N (p.p.m.)	Stabil. (%)	4-Hr. O/A (p.p.m.)	B.O.D. (p.p.m.)	Stabil. (%)
Moderate	Cydna	2½, 1	147	42	64	200	6,200	11	27	100	7	9	100
	Bruma	¾	100	64	100	350	6,400	15	21	100	7	5	100
Slight overload	Antea	1	118	95	329	—	11,100	30	6	57	21	30	95
	Klipspruit I	2–3	125	96	145	450	12,000	24	3	80	—[4]	—[4]	—[4]
	Klipspruit II	2–3	265	45	143	—	11,900	14	14	100	14	7	100
			66[5]	96[5]		450[5]	6,300[5]						
Heavy overload	Delta	2–3	298	81	80	350	24,100	21	1	38	16	28	59
	Klipspruit III	1–3	294	96	145	450	28,200	42	0	10	—[4]	—[4]	—[4]

[1] Imperial gallons. [2] Oxygen absorbed from permanganate in 4 hr. [3] Strength × rate of flow. [4] No sand filtration. [5] Sewage added to effluent from Group I filters to give mixture shown for Group II filters.

Standards for Discharges of Sewage and Industrial Wastes. By Louis Bastita, Jorge A. Pigretti, and Juan A. Raggio. *Revista de Obras Sanitarias de la Nacion* (Argentina), No. 155 (Oct.–Dec., 1953).

Definition of the physical and chemical characteristic limits is given for the permissible discharge of industrial and sewage wastes. Recognition is given as to variations that may be expected in special cases. Limits are given for discharges (a) into collecting sewers, (b) into storm sewers and their outfall units, and (c) directly into watercourses. Waste characteristics defined for these discharges are given for temperature, pH, settleable solids (10 min.), settleable solids (2 hr.), B.O.D., oxygen consumed, and chlorine demand. Performance qualifications are also established for greases, oils, and for other foreign materials which may impede the proper function of sewers or sewage treatment works, produce odor problems, or which may otherwise cause nuisance, toxic risks, fire hazard, etc. The standards have incorporated basic data used in daily practice by the National Sanitary Works agency of the Argentine government. L. D. Hudson

Outfall Sewer for the City of San Francisco (Province of Cordoba). *Revista de Obras Sanitarias de la Nacion* (Argentina), No. 156 (Jan.–Feb., 1954).

Engineering reasons are summarized for the construction of a 34.4-km. outfall sewer for the City of San Francisco. Construction of this 0.7-m. diameter sewer was started January 27, 1954, to carry wastes from the sewage treatment plant for discharge into the existing San Antonio irrigation system.

The outfall conduit is designed to serve an estimated future population in 1978 of 57,500 inhabitants. The present urban population is 27,000. The decision to proceed with the long outfall was reached after an extensive study of land irrigation, absorption field, evaporation areas, and of the alternate watercourses. Use of the San Antonio irrigation system proved most advantageous; the portion of this irrigation system receiving the discharge will not be used for either direct land irrigation or for a source of domestic water consumption; the temporary discharge of untreated sewage to the irrigation will not create insanitary conditions to the rural people; and utilization of the present drainage system will minimize maintenance expense. L. D. Hudson

Concerning the Main Drainage of London. By W. P. Warlow. *Proc. Inst. Civ. Eng.*, **3**, 356 (1954).

This article reviews the history of London's sewer system and its effect on pollution of the Thames River. Although chemical sedimentation of sewage was practiced from the 1880's on, it is no longer used. However, one-third of the settled sewage at the Northern Outfall works currently undergoes activated sludge treatment. Screenings are composted with household refuse and some of the sludge is digested, the residue being barged to sea.

The area of 114,277 acres is drained mainly on the combined system, storm water being allowed for at the rate of $\frac{1}{4}$ in. per hour. Considerable pumping is necessary. Peter C. G. Isaac

Sewage Disposal Works Design—Preliminary Stages. By D. Johnson. *Jour. Inst. Mun. Eng.*, **80**, 343 (1953–4).

In dealing with the principles of sewage treatment the author covers (a) analysis of sewage and sewage effluents by the B.O.D., O.A., suspended solids, and relative stability tests; (b) the quantity of domestic sewage and trade wastes; and (c) the rates of treatment based on the recommendations of the Royal Commission on Sewage Disposal (1915). He also considers the design of screens, covering the use of comminutors and disintegrators. A theory of sedimentation is given, followed by its applications and general practice in the design of grit channels and sedimentation basins.

Appendices give (a) typical sewage analyses; (b) the required effluent dilution calculated from the B.O.D. test and a proposed standard for effluents; (c) factors for estimating the quantity of trade wastes; and (d) the settling velocity of particles. R. N. Field

A Method of Simplifying Soil Percolation Tests for Septic Tank Systems. By A. Gelperin and W. O. Fuller. *Pub. Health Rep.*, **68**, 693 (1953).

This is essentially a description of an automatic soil percolation timer of simple

construction that depends on a float-actuated clock mechanism. H. P. O.

An Investigation of the Performance of Six Small Septic Tanks. By E. R. Baumann and H. E. Babbitt. Bull. Series No. 409, Univ. of Illinois Eng. Experiment Sta. (1953).

To evaluate the performance of six steel septic tanks, simultaneous tests were conducted with retention periods varying between 6 and 48 hr. Tank effluents were analyzed for suspended and settleable solids, as a measure of the tank's ability to remove solid materials from the liquid. Tests also were made for volatile solids and B.O.D. as a measure of the tank's ability to reduce the polluting power of the effluent. Table II contains generally descriptive material on the tanks investigated.

General conclusions have been drawn from the tests as follows:

1. The Imhoff-type septic tanks provide the best removal of settleable and suspended solids.

2. The ordinary septic tanks utilizing the disturbed digesting solids for seeding provide the best reduction in the tank effluent B.O.D. and turbidity.

3. Gas deflection baffles are effective in the prevention of tank unloading and in the reduction of the normal carry-over of solids into the effluent.

4. Influent deflection baffles are essential in order to provide a high percentage of experimental detention time compared to theoretical detention time.

5. A tank utilizing both gas-disturbed particles for seeding and a gas-protected sedimentation chamber for the prevention of solids carry-over, should be the most effective septic tank for ordinary installations.

6. Imhoff-type tanks should use at least one-third of the tank capacity for the flowing-through chamber.

With respect to the design of the six septic tanks utilized in this study the following conclusions were drawn:

7. Tank I, if provided with an effluent gas deflection baffle, should provide economical and effective operation in most small installations.

8. Tank II gave unsatisfactory treatment due to its insufficient retention period and sludge storage space.

9. Tank III provided very effective performance for short periods, but contains too little sludge storage space for general use. The sludge storage space, now 20 per cent of the total, should be increased to at least 40 to 45 per cent with a reduction of the waste or scum space.

10. Tank IV provided an unsatisfactory effluent. The effectiveness of tanks III and V indicates that they should be used in preference to tank IV.

11. Tank V provided the best operating tank for general installation, but should be provided with an influent baffle. In all probability, the effectiveness of the tank would not be impaired if it were reduced to a two-compartment tank equipped with gas-protected sedimentation chambers. The vertical baffle of the gas-protected chamber should be extended to at least 4 in. above the liquid surface to prevent solids passing over the top of the baffle.

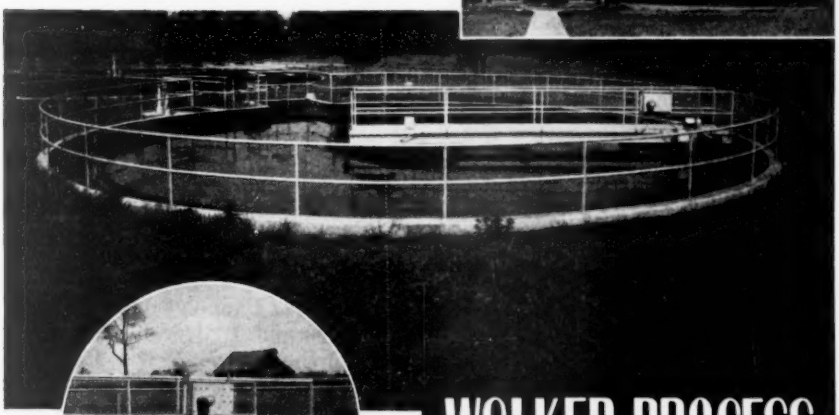
12. Tank VI produced a poor effluent and should not be utilized as a septic tank.

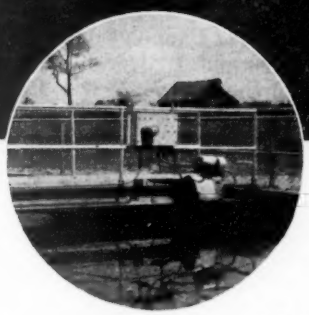
H. P. Orland

TABLE II.—General Description of Septic Tanks Tested

Tank No.	Size		Type
	(in.)	(gal.)	
I	51¾ dia. × 60 deep	470	Single compartment
II	55 × 60 oval × 76½ long	765	Imhoff, two compartments
III	27½ × 60 oval × 93 long	511	Imhoff, two compartments
IV	36 × 108 × 60 deep	810	Two compartments, series
V	36 × 144 × 60 deep	1,080	Three compartments, series
VI	47½ dia. × 50 deep	340	Single compartment

Farmington, Mo. Sewage Disposal Plant uses...





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The sewage treatment plant at Farmington, Missouri includes a number of Walker Process units.

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The 39′ diameter Floating Cover on the digester is designed so that no truss or frame work protrudes above the tank. Constant gas pressure is maintained. Ballast and counter weights are suspended below the cover as positive prevention against overturning.

The Walker Process HeatX accomplishes sludge heating outside the digester. This self contained unit includes control panel, burner, hot water tube boiler and shell, and tube exchanger. It operates on natural and sewage gas.

Consulting Engineer:	Charles A. Haskins Kansas City, Mo.
Superintendent:	Frank Zimmer
Chief Operator:	Otha Parker

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Proceedings of Member Associations

KANSAS SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Kansas Sewage and Industrial Wastes Association held its 1954 Annual Meeting in the Broadview Hotel, Emporia, Kans., on April 7–9, 1954, in conjunction with the Kansas Section, AWWA. Registration totaled 219, including 35 ladies.

Papers were presented as follows:

"Flush Tank Elimination," a panel discussion (see THIS JOURNAL, **26**, 7, 923 (July, 1954).

"Methods of Sludge Disposal," a panel discussion.

"Solving the Grit Removal Problem," a panel discussion.

"Petroleum Refinery Waste Treatment," by Gordon E. Mau, Kansas State Board of Health, Lawrence.

"Basis of Changing from One-Stage to Two-Stage Digestion," by E. Weatherford, Chemist, Mission Twp., Main Sewer District No. 1.

"Digester Control at Wichita," by V. Pickering, Chemist, Sewage Treatment Plant, Wichita.

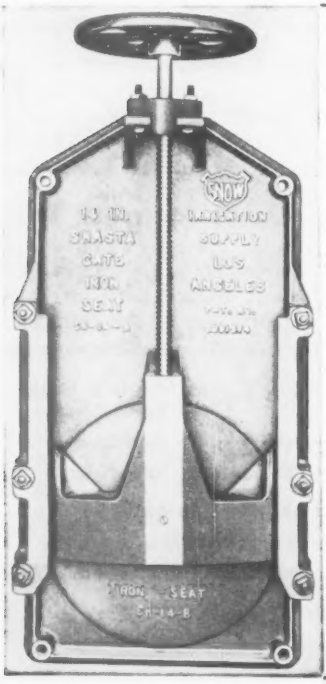
"Oil and Silt Traps," by A. J. Jefferis, City Engineer, Ottawa.

Officers were elected as follows:

Chairman: L. Cunningham, Parsons.
Vice-Chairman: L. Beyer, McPherson.
FSIWA Director: M. Nelson, Mission.
Secretary-Treasurer: R. H. Hess, Wichita.

ROBERT H. HESS,
Secretary-Treasurer

(*Continued on page 366a*)



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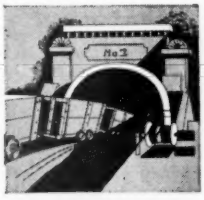

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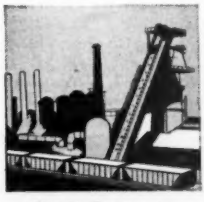
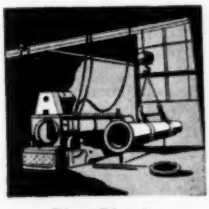

Blast Furnaces


Pipe Plants

ALABAMA WATER AND SEWAGE ASSOCIATION

The 1954 Annual Meeting of the Alabama Water and Sewage Association was held June 7–9, 1954 at the Alabama Polytechnic Institute, Auburn, Ala., in conjunction with the 9th Annual Short Course School. A total of 125 persons registered.

Arthur N. Beck, Chief Sanitary Engineer, Alabama State Dept. of Health was nominated to receive the Federation's Bedell Award.

Officers were elected as follows:

President: C. Lamon, Prichard.
Vice-President: C. L. Gray, Birmingham.
FSIWA Director: J. L. Crockett, Jr., Montgomery.
Treasurer: L. Hubbs, University.
Secretary: W. L. Samuel, Auburn.

W. L. Samuel,
Secretary

VIRGINIA INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 8th Annual Meeting of the Virginia Industrial Wastes and Sewage Works Association was held at the Stonewall Jackson Hotel, Staunton, Va., May 20–21, 1954. Registration for the meeting totaled 137, including 26 ladies.

Papers were presented as follows:

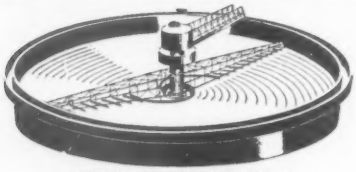
"Licensing of Water and Sewage Plant Superintendents in New Jersey," by Louis J. Fontenelli, Superintendent, Rahway Valley Sewage Treatment Plant, Garwood, N. J.

"Use of Aquatic Organisms as a Measure of Stream Conditioning," by R. Patrick, Curator of Limnology, Academy of Natural Sciences of Philadelphia, Pa.

"Pollution Abatement Program at

(*Continued on page 368a*)

HARDINGE WATER, SEWAGE, TRADE-WASTE EQUIPMENT



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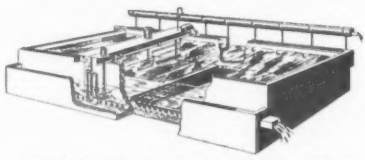

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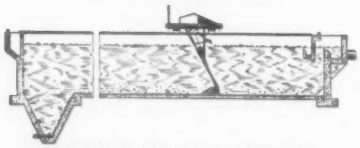

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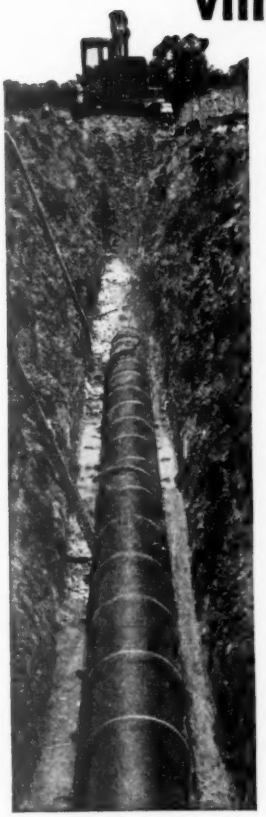

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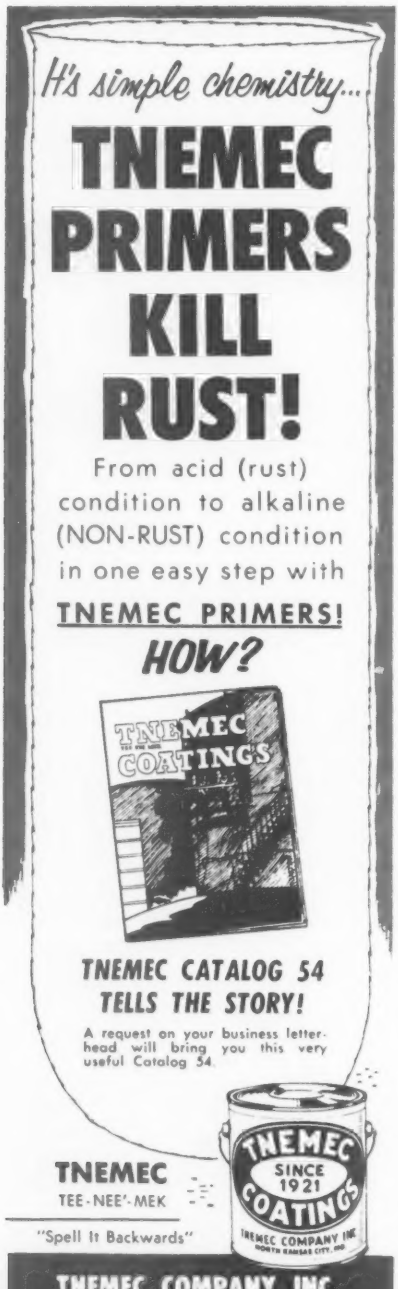
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Crompton-Shenandoah Company," by D. Snyder, Plant Chemist, Waynesboro, Va.

"Deterioration of Sewers and Structures Caused by Hydrogen Sulfide, Acids, and other Corrosive Materials," a panel discussion.

Inspection trips were made to the Rockingham poultry packing plant, Stuart's brewery, and the Crompton-Shenandoah Co., Waynesboro.

The following officers were elected:

President: F. H. Miller, Norfolk.
Vice-President: L. R. Albert, Hopewell.
Secretary-Treasurer: J. L. Hamrick, Jr., Richmond.

J. L. HAMRICK, JR.,
Secretary-Treasurer

MONTANA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 10th Annual Meeting of the Montana Sewage and Industrial Wastes Association was held at the Baxter Hotel, Bozeman, Mont., on April 22, 1954. Registration for the meeting totaled 55.

Papers presented were as follows:

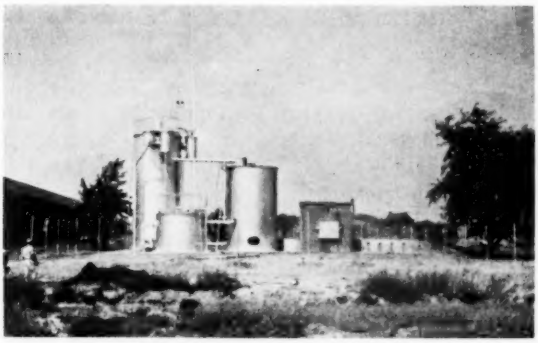
"Sewage Lagoons," by W. J. Wenzel, Consulting Engineer, Great Falls, and C. W. Brinck, Montana State Board of Health, Helena.

"Operation of Primary Sewage Treatment Plants," by D. L. Anderson, Superintendent of Sewage Treatment, Bozeman, and M. F. Dixon, Superintendent of Water Purification, Billings.

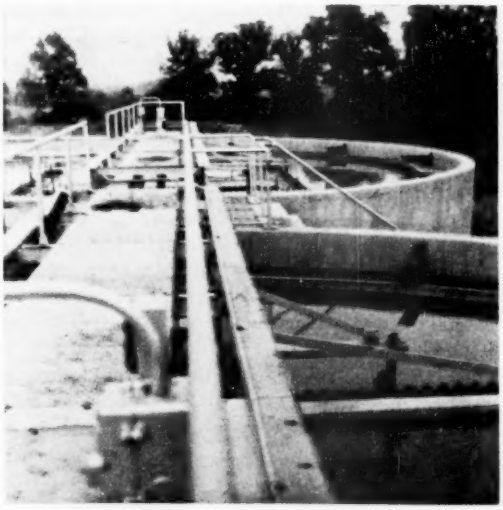
Officers were elected as follows:

Chairman: D. L. Anderson, Bozeman.
Vice-Chairman: M. F. Dixon, Billings.
FSIWA Director (to 1956): F. F. Palmer, Forsythe.
Secretary-Treasurer: H. W. Taylor, Helena.

HARVEY W. TAYLOR,
Secretary-Treasurer



An 8 ft. dia. Spiragester, 9 ft. dia. trickling filter and an 8 ft. dia. hoppered bottom final Spiraflo Clarifier. All three units are of steel construction, for an Industrial Waste Treatment Plant.



Two 45 ft. dia. Primary Spiraflo Clarifiers at Troy, Ohio. Note the clean surfaces. Floating materials are caught behind the skirt.

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Equipment and Supply Lines

Valve Operators—Air motors for operating various valves and other equipment are described in Bulletin 414–1.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Butterfly Valves—Bulletin 1701 describes air-operated butterfly valves for flow control.—Minneapolis-Honeywell Regulator Co., Philadelphia 44, Pa.

Sampler—Trebler samplers for sewage, industrial wastes, or other liquids, with or without time-clock control, are described in Bulletin 131.—Lakeside Engineering Corp., 222 W. Adams St., Chicago 6, Ill.

Concrete Pressure Sewer Pipe—New 4-page folder describes and gives specifications on steel and rubber joint concrete pressure sewer pipe.—Price Brothers Co., 1932 E. Monument Ave., Dayton 1, Ohio.

Fluid Flow Meter—A new device known as the Dall Flow Tube meters fluids carrying no settleable solids.—Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.

Treatment Equipment—Bulletin AH 442 describes equipment and typical flow diagrams for treatment of water, sewage, and industrial wastes.—Hardinge Co., Inc., 240 Arch St., York, Pa.

Lubricated Plug Valves—8-page brochure describes all types and sizes of lubricated plug valves for light-and heavy-duty service.—American Car and Foundry Co., 1501 E. Ferry Ave., Detroit 11, Mich.

Portable Generator—Engine-driven electric generator plant provides both electrical and belt-driven power simultaneously from portable unit.—Lynn Engineering & Supply Co., Russ Bldg., San Francisco 4, Calif.

Dual-Fuel Engines—New 36-page Bulletin S–500–B57 describes dual-fuel engines and accessories, together with examples of applications, case histories, and vital statistics.—Worthington Corp., Harrison, N. J.

Pump Sequence Controls—Automatic pump sequence control systems for multiple pump installations are described in Catalog 91–106.—Fischer & Porter Co., Hatboro, Pa.

Flow Regulator—Catalog 10–F–70 describes a new self-contained flow regulating device for clean gas-free liquids.—Fischer & Porter Co., Hatboro, Pa.

Sewage Plant Engines—Bulletin WP–1099–B3 contains design, selection, and application information on dual-fuel, spark ignition, and diesel engines for sewage plant use. The bulletin also covers compressors, vacuum pumps, centrifugal and rotary pumps, and equipment for handling raw sewage, effluent, and sludge.—Worthington Corp., Harrison, N. J.

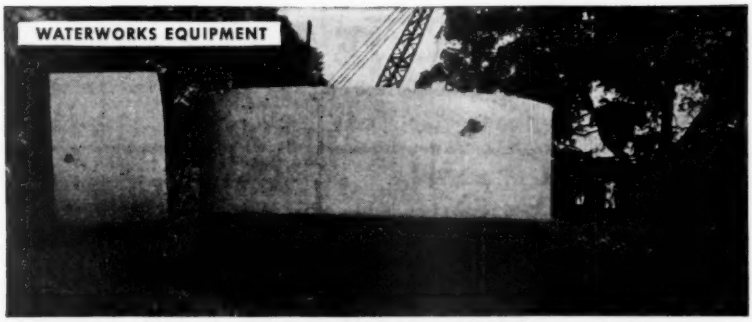
Pipe Laying Instructions—15-page handbook gives detailed illustrated instructions for laying concrete pressure pipe.—Price Brothers Co., 1932 East Monument Ave., Dayton 1, Ohio.

Chlorinator—A new dual-orifice chlorinator with feed ranges up to 100 to 1 has a maximum capacity of 1,000 lb. per 24 hr.—Wallace & Tiernan, Inc., Belleville 9, N. J.

Centrifugal Pumps—Bulletin W–318–S27 describes two-stage centrifugal pumps for pressures up to 400 p.s.i. and capacities up to 1,300 g.p.m.—Worthington Corp., Harrison, N. J.

D. O. Analyzer—New dissolved oxygen analyzer of amperometric type is not subject to the usual interferences of the Winkler test.—Dorber Co., 7741 W. Palatine Ave., Chicago 31, Ill.

Nylon Filter Cloth—A new spun nylon filter cloth has important nonblinding properties on continuous filtration applications.—Filtration Fabrics Div., Filtration Engineers, Inc., 155 Oraton St., Newark 4, N. J.



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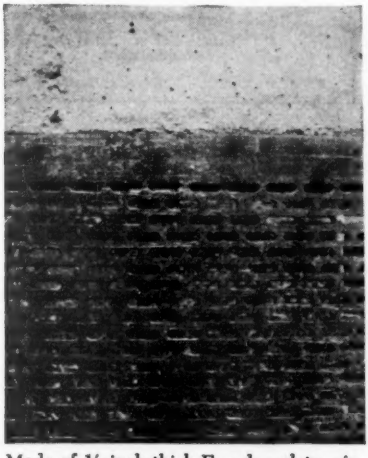

Made of ¼-inch-thick Everdur plate, circular screens are 18 inches high, having ¼-inch oblong perforations. Total open area is about 37%.

Caisson Wells, Inc., of New York City, did the job. Jordan S. Asketh of this company conducted the exploratory work. Wallace M. Graves, Consulting Engineer, Bound Brook, N. J., was in charge. Edward Purzicki was Waterworks Superintendent.

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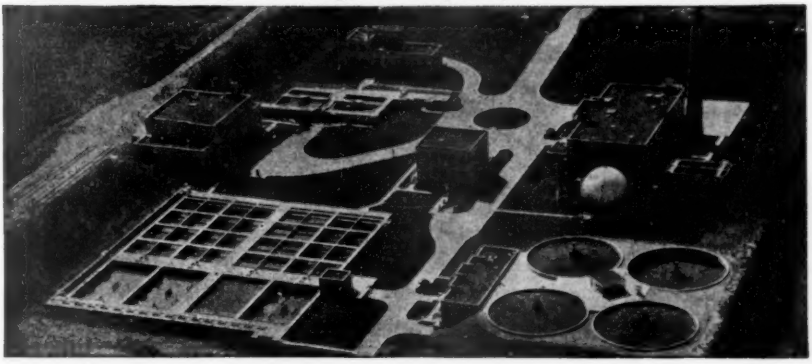

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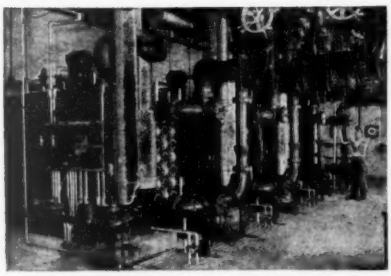

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Second — A new dual purpose unit for small plants which combines in the same tank effective grit removal followed by primary sedimentation in a standard Dorr Clarifier.

And of course our staff will be on hand to discuss the complete Dorr line of equipment covering practically every step in every sewage treatment flowsheet. Make a note now to visit the Dorr booth in Cincinnati.

Better tools TODAY to meet tomorrow's demand

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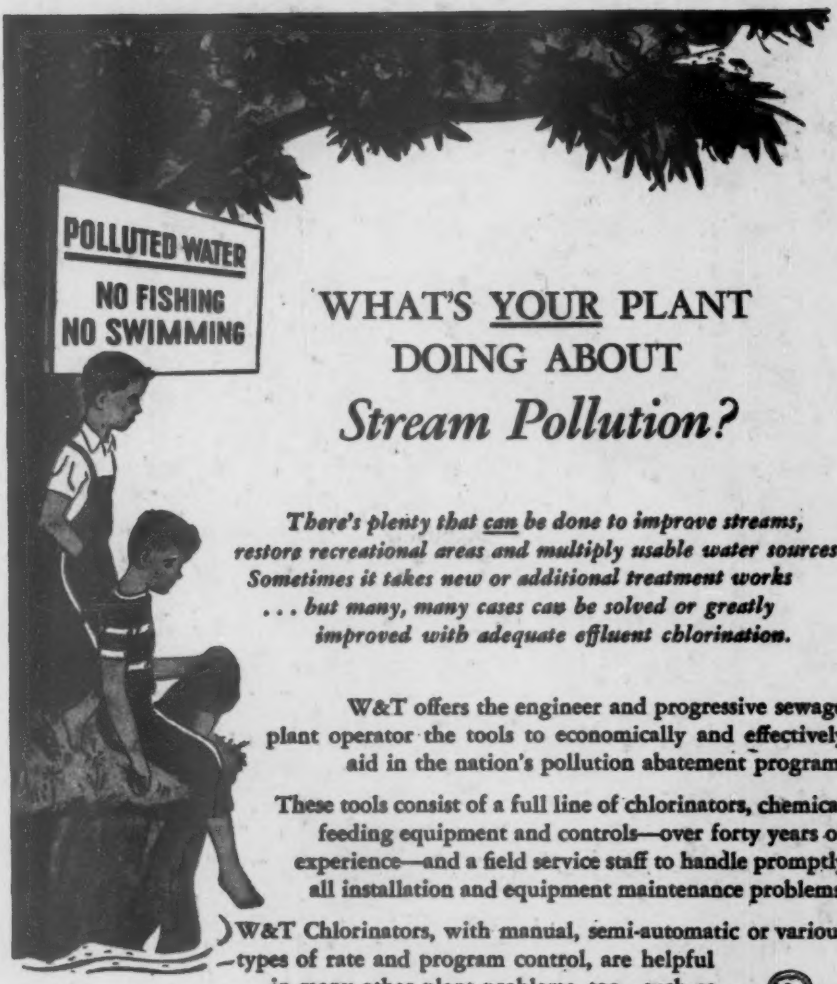

WHAT'S YOUR PLANT DOING ABOUT *Stream Pollution?*

There's plenty that can be done to improve streams, restore recreational areas and multiply usable water sources. Sometimes it takes new or additional treatment works . . . but many, many cases can be solved or greatly improved with adequate effluent chlorination.

W&T offers the engineer and progressive sewage plant operator the tools to economically and effectively aid in the nation's pollution abatement program.

These tools consist of a full line of chlorinators, chemical feeding equipment and controls—over forty years of experience—and a field service staff to handle promptly all installation and equipment maintenance problems.

W&T Chlorinators, with manual, semi-automatic or various types of rate and program control, are helpful in many other plant problems, too—such as grease removal, filter ponding prevention and septicity reduction, to mention just a few.

Why not start your community on the road to clean streams? Your W&T Representative will be glad to help, without obligation, of course.

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